RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA

VOLUME XLIX

Published by order of the Government of India

CALCUTTA;
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY OF INDIA,
27, CHOWRINGHEE ROAD
LONDON: MESSRS. WILLIAM WESLEY & SON.

1919

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VOL. XLIX, PART I.

1918.

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Part 3.—Maskat and Massandim on east coast of Arabia. Example of local jointing. Axial group of Western Prome. Geology of Bombay Presidency.

Part 4.—Coal in northern region of Satpura basin. Evidence afforded by raised oyster banks on coasts of India, in estimating amount of elevation indicated thereby. Possible field of coal-measures in Godavari district, Madras Presidency. Lameta or intra-trappean formation of Central India. Petroleum localities in Pegu. Supposed eozoonal limestone of Yellam Bile.

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Part 4 (out of print).—Auriferous rocks of Dhambal hills, Dharwar district. Antiquity of human race in India. Coal recently discovered in the country of Luni Pathans, south-east corner of Afghanistan. Progress of geological investigation in Godavari district, Madras Presidency. Subsidiary materials for artificial fuel.

Vol. VIII, 1875.

Part 1.—Annual report for 1874. The Altum-Artush considered from geological point of view. Evidences of 'ground-ice' in tropical India, during Talchir period. Trials of Raniganj fire-bricks.

Part 2.—Gold-fields of south-east Wynaad, Madras Presidency. Geological notes on Khareean hills in Upper Punjab. Water-bearing strata of Surat district. Geology of Scindia's territories.

Part 3 (out of print).—Shahpur coal-field, with notice of coal explorations in Narbada regions. Coal recently found near Moflong, Khasia Hills.

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Vol. IX, 1876.

Part 1.—Annual report for 1875. Geology of Sind.

Part 2 (out of print).—Retirement of Dr. Oldham. Age of some fossil floras in India. Cranium of Stegodon Ganesa, with notes on sub-genus and allied forms. Sub-Himalayan series in Jamu (Jammoo) Hills.

Part 3 (out of print).—Fossil floras in India. Geological age of certain groups comprised in Gondwana series of India, and on evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. Relations of fossiliferous strata at Maleri and Kota, near Sironcha, C. P. Fossil mammalian faunæ of India and Burma.

Part 4 (out of print).—Fossil floras in India. Osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Plesiosaurus in India. Geology of Pir Panjal and neighbouring districts.

Vol. X, 1877.

Part 1.—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. Estheria in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Emydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.

Part 2 (*out of print*).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack. Fossil floras in India. New or rare mammals from the Siwaliks. Arvali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.

Part 3 (*out of print*).—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing-machine used by smiths of Upper Assam. Analyses of Raniganj coals.

Part 4 (*out of print*).—Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barrovensis,' McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

Vol. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2 (*out of print*).—Geology of Sind (second notice). Origin of Kumaun lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.

Part 3.—Gold industry in Wynaad. Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—Geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Siwalik mammalia. Siwalik birds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan). Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal-basin. Coal importations into India.

Part 2.—Mohpani coal-field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kurram at Thal on Afghan frontier. Geology of Upper Punjab.

Part 3.—Geological features of northern Madura, Pudukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Nerbudda.

Part 4.—'Attock Slates' and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Fossil plants from Kattywar, Shekh Budin, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3.—Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4.—Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated wih basaltic rocks of north-eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas.' Mammalian fossils from Perim Island.

Part 2.—Nahan-Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain; and Coal and Metalliferous Mines Acts of 1872 (England). Cobaltite

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] **1918.** **[May**

GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1917. BY H. H. HAYDEN, C.I.E., F.R.S., *Director, Geological Survey of India.*

CONTENTS.

DISPOSITION LIST.

1. During the period under report, the officers of the Department were employed as follows :—

Superintendents.

MR. C. S. MIDDLEMISS — At headquarters till March 31st, 1917. Retired from Government service with effect from April 1st, 1917.

MR. E. VREDENBURG . At headquarters as Palæontologist. Deputed to report on an occurrence of molybdenite at Palni. Madura district from February 11th to March 11th, 1917.

DR. L. L. FERMOR . Services lent to the Railway Board in connection with the exploration of the western portion of the Bokaro coal-field from January 1st, 1917, to March 30th, 1917. Services placed at the disposal of the Indian Munitions Board with effect from April 1st, 1917, to September 30th, 1917. Engaged in the examination of the mica deposits of Ajmer and Orissa during the remainder of the year.

DR. E. H. PASCOE . Appointed Superintendent *vice* Mr. Middlemiss (retired), with effect from April 1st, 1917. Reverted from military duty on April 14th, 1917. At headquarters till October 17th, 1917; afterwards engaged on the investigation of the oil occurrences of the Punjab.

Assistant Superintendents.

DR. G. E. PILGRIM . Reverted from military duty with effect from October 24th, 1917. Engaged in the investigation of an artesian water supply for Bandar Abbas.

MR. G. H. TIPPER .	Reverted from military duty with effect from April 5th, 1917. From 8th to 27th July attached to the Waziristan Field Force. Engaged in the investigation of mica deposits of Kodarma and its neighbourhood from October 22nd, 1917.
MR. H. WALKER .	As Curator at headquarters from the afternoon of January 23rd to the afternoon of March 16th, 1917. Investigated alleged occurrences of molybdenite and wolfram in Palni and Kadavur in April and May, 1917. Engaged on the investigation of the mica deposits of Sambalpur from November 2nd, 1917.
MR. K. A. K. HALLOWES	Returned from the field on May 14th, 1917. Posted to the Central Provinces and left for the field on November 4th, 1917.
MR. G. DE P. COTTER .	Appointed Curator, Geological Museum and Laboratory. From January 23rd to February 28th, 1917, employed on revision of the geological map of the Jherria coalfield.
MR. J. C. BROWN .	Employed in Tavoy in connection with the wolfram-mining industry.
MR. H. C. JONES .	Reverted to civil employ on the afternoon of September 30th, 1917. Engaged in investigating the mica deposits of Udaipur State from October 21st, 1917.
MR. A. M. HERON	Returned from the field on the afternoon of July 10th. Left headquarters for Tavoy on October 9th, 1917.

DR. M. STUART . .	Returned from the field on May 11th, 1917. Acted as Lecturer on Geology, College of Engineering, Poona, from June 11th to October 3rd, 1917. Posted to Putao, Burma, and left for the field on November 13th, 1917.
MR. N. D. DARU .	Returned from the field on March 30th, 1917. Granted privilege leave combined with furlough on medical certificate for one year with effect from May 1st, 1917.
MR. C. S. FOX . .	Reverted to civil employ on August 2nd 1917. Left for the field to investigate bauxite deposits in Chota Nagpur and Sarguja on September 27th. 1917.
MR. R. W. PALMER .	On military duty.

Chemist.

DR. W. A. K. CHRISTIE	Reverted to civil employ with effect from August 2nd, 1917. At headquarters.

Artist.

MR. K. F. WATKINSON	Returned from privilege leave with effect from March 1st, 1917. At headquarters.

Sub-Assistants.

MR. S. SETHU RAMA RAU.	Returned from the field on April 30th, 1917. Granted privilege leave for 27 days from September 19th, 1917. Left for Tavoy on October 23rd, 1917.

MR. VINAYAK RAO . Returned from the field on April 23rd, 1917. Granted privilege leave for two months and 15 days from April 24th, 1917. Left for Tavoy on October 23rd, 1917.

Assistant Curator.

MR. A. K. BANERJEE . In charge of the laboratory at Tavoy. Granted privilege leave for one month from May 14th, 1917. Returned to headquarters on December 12th, 1917.

ADMINISTRATIVE CHANGES.

Retirement and Promotions.

2. Mr. C. S. Middlemiss, C.I.E., Superintendent, retired with effect from April 1st, 1917. Dr. E. H. Pascoe was promoted to the grade of Superintendent from April 1st, 1917, *vice* Mr. C. S. Middlemiss.

3. Mr. H. Walker officiated as Superintendent from January 1st, 1916, to June 4th, 1916, and from November 1st, 1916, to March 30th, 1917, *vice* Dr. L. L. Fermor, deputed to the Bokaro coalfield. From April 1st to 4th, 1917, he officiated as Superintendent, *vice* Dr. L. L. Fermor, on deputation under the Indian Munitions Board, and from April 5th to 13th, *vice* Dr. E. H. Pascoe on military duty.

Mr. G. deP. Cotter officiated as Superintendent from April 1st to 4th, 1917, *vice* Dr. E. H. Pascoe on military duty.

Mr. G. H. Tipper was appointed to officiate as Superintendent from April 5th to September 30th, 1917, *vice* Dr. L. L. Fermor, on deputation under the Indian Munitions Board.

Leave.

4. Mr. K. F. Watkinson returned from privilege leave and resumed his duties as Artist with effect from March 1st, 1917.

Mr. N. D. Daru was granted privilege leave combined with furlough on medical certificate for a period of 12 months with effect from May 1st, 1917.

Mr. A. K. Banerjee was granted privilege leave for one month with effect from May 14th, 1917.

Sub-Assistant S. Sethu Rama Rau was granted privilege leave for 27 days with effect from September 19th, 1917.

Sub-Assistant M. Vinayak Rao was granted privilege leave for 2 months and 15 days with effect from April 24th, 1917.

RETIREMENT OF MR. MIDDLEMISS.

5. To the regret of his colleagues Mr. C. S. Middlemiss retired from the Geological Survey on March 31st, 1917. Mr. Middlemiss joined the Department in September, 1883, and had completed over 33½ years' service at the time of his retirement. During that period, his work took him to almost every part of the Indian Empire. In the early part of his service he was employed chiefly in the Himalaya, where he at once made his mark by the discovery in the Tal Series—till then only known to contain comminuted fragments of shells—of fossils, not fully determinable, it is true, but generally agreed to be Mesozoic, thus giving an approximate datum for the partial correlation of the local rocks. Mr. Middlemiss's subsequent Himalayan and Sub-Himalayan work was equally notable, and his memoir on the Sub-Himalaya of Kumaun and Garhwal is one of the classic works on Himalayan stratigraphy. Other valuable stratigraphical work was done by him in the Naini Tal region, in Hazara, in the Salt Range, in the Southern Shan States and in Rajputana, while, during the last few years of his service, he has recast completely our ideas on the subject of the geology of Kashmir. Stratigraphy, however, is only one aspect of his many-sided geological activity, which has embraced also wide petrographic study of the crystalline rocks of the Madras Presidency, of the Vizagapatam Hill-tracts and of the Himalaya, investigation of several Indian earthquakes, including the great Kangra earthquake of 1905, and valuable work on the stability of mountain slopes in India and Ceylon. The value of Mr. Middlemiss' contributions to science was recognised by the Geological Society of London in 1914, when he was presented with the Lyell Medal, while in the following year the Government of India marked their appreciation of his services to the State by conferring on him the C. I. E. He is also a Fellow of the Asiatic Society of Bengal, and in 1917 was President of the Geological Section of the Indian Science Congress.

After leaving the Geological Survey Mr. Middlemiss accepted the post of Superintendent of the Mineral Survey of Kashmir

where his intimate knowledge of the local geology will prove of great value to the Durbar in their endeavour to develop the resources of the State.

MILITARY SERVICE.

6. During the year, it was found necessary, owing to pressure of work, to recall most of the members of the Geological Survey who had taken commissions, and Dr. G. E. Pilgrim, Mr. G. H. Tipper, Dr. E. H. Pascoe, Messrs. H. C. Jones, and C. S. Fox and Dr. W. A. K. Christie resumed their civil appointments,—Drs. Pilgrim and Pascoe from Mesopotamia, Mr. Tipper from Egypt, Mr. Jones from Jubbulpore, after return from France, and Messrs. Christie and Fox from the Western Front.

STUDENTS.

7. Babu Harendra Mohan Lahiri, M.Sc., holding a post-graduate scholarship under the Government of Bengal, was permitted to carry on research work in the Museum and laboratory of the Geological Survey throughout the year.

PROFESSORSHIPS AND LECTURERSHIPS.

8. Mr. G. de P. Cotter was Lecturer on Geology at the Presidency College, Calcutta, throughout the year.

Dr. M. Stuart was Lecturer on Geology at the Engineering College, Poona, from June 11th to October 3rd, 1917.

Mr. E. Vredenburg was appointed Professor of Geology at the Calcutta University in addition to his own duties, with effect from September 1st, 1917.

LIBRARY.

9. The additions to the library during the year 1917 amounted to 2,083 volumes, of which 862 were acquired by purchase and 1,221 by presentation and exchange.

PUBLICATIONS.

10. The publications issued during the year under review comprise one volume of ***Records***, two of ***Memoirs*** and one memoir of ***Palæontologia Indica.***

MUSEUM AND LABORATORY.

Staff.

11. Mr. G. de P. Cotter was Curator of the Geological Museum and Laboratory throughout the year, with the exception of a period extending from the 23rd January to the 16th March, during which that office was held by Mr. H. Walker. The Assistant Curator, Mr. A. K. Banerji, returned from Tavoy to headquarters on December 12th. Babu Baroda Charan Gupta continued to work in the Laboratory throughout the year, and Babu Phanindra Nath Mukerji, who was appointed as probationary Museum Assistant on October 19th, 1916, was confirmed in his appointment on the 19th March.

12. Dr. W. A. K. Christie was recalled from military duty in France, and rejoined the department on the 2nd August, 1917.

Determinative work and analyses.

13. The number of specimens referred to the Laboratory for examination and report was 600, as against 310 in the preceding year. Of these assays and analyses were made of 83 specimens as compared with 40 analyses in the preceding year.

Meteorites.

14. Two meteorite falls were recorded in 1917. The first fell at Ranchapar in the Babupur taluq, Kundahit Circle, Jamtara subdivision, Santhal Parganas, (see Bengal standard sheets, 1″=1 mile, nos. 235 and 236.) The meteorite fell between 8 and 9 A.M. on February 20th. Four fragments were received, weighing respectively 148·42 grammes, 140·31 gr., 0·29 gr., and 77·85 gr. The smallest fragment was used for a microscope section. The meteorite is being examined by Mr. Walker. The second meteorite fell at Cranganorein the Cochin State (10° 11′ 30″; 76° 16′ 3″). The fall occurred at 12-45 P.M. on July 3rd. Seven fragments were received, weighing as follows :—

A, 445·3 grammes, B, 29·14 grammes, C, 10·22 grammes, D, 5·52 grammes, E (dust in tube), 0·90 grammes, F, 255·8 grammes, G, 713·36 grammes. This meteorite is a veined white chondrite.

Donations.

15. During the year collections of rocks and minerals were given to—

(1) Central Hindu College, Benares—a school collection of minerals and rocks ;

(2) Ewing Christian College, Allahabad—a similar collection ;

(3) Idar State Durbar—a duplicate collection of all the more important specimens collected by Mr. C. S. Middlemiss in the Idar State ;

(4) Pratt Memorial School, Calcutta—a school collection of minerals and rocks;

(5) Dr. Boswell, College of Science, South Kensington—a collection of Indian sands for glass-making;

(6) Mr. T. J. Warth, Agricultural Chemist, Burma—specimens of dolomite and magnesite;

(7) The Islamia High English School, Rangpur—a school collection of minerals and rocks;

(8) Sedgwick Museum, Cambridge—a very complete collection of the economically important minerals of India was selected and packed, but has not yet been dispatched.

Additions to the collections.

16. The following foreign specimens were added to the collections during the year—

(1) Phlogopite in calcite from Goanikamtes near Swakopmund, north of Walfish Bay, S. W. Africa, presented through Mr. C. S. Fox by Major F. O. Howes, 10th S. African Infantry, Durban;

(2) Scheelite, cassiterite, wolfram and other commoner minerals from the Kinta district, Malay Peninsula, presented by Mr. J. M. Wilson.

Amongst the many Indian specimens received, the following may be mentioned:—

(1) Intergrowth of gold crystals found in a mercury riffle during extraction, presented by the Mysore Gold Mining Co., Ld.;

(2) gold with tetradymite from the North Anantapur Gold Mine, presented by Messrs. John Taylor and Sons.

(3) wolfram crystals, scheelite, bismuthinite, and native bismuth, presented through Mr. J. C. Brown, from various mines in Tavoy;

(4) crystals of cassiterite from Chanchal Pahar, Moheshpur, Domchanch, Hazaribagh district, presented by Mr. J. Podger;

(4) samarskite in quartz, from a pit near Yedur village, 2 miles south of Bangalore, presented by Mr. V. S. Sambasiva Iyer;

(5) monazite from Abraki Pahar, Singar zemindari, Gaya district, presented by the late Mr. H. E. Tiery.

Rearrangement of Fossil Gallery.

17. During the year the packing of specimens in the drawers beneath the show-cases has been completed. The rearrangement of the show-cases of Indian fossils is also approaching completion, although the printing of labels is still unable to keep pace with the work of rearrangement. The upper Jurassic, Cretaceous, and part of the Tertiary show-cases have been completely revised; the Jurassic collections of Kachh and Spiti have been arranged according to the classification of Uhlig and Waagen respectively. In the rearrangement of the Cretaceous of South India, Kossmatt's classification and nomenclature of the ammonites has been followed. The Tertiary collections are now being rearranged in accordance with the recent work done by Vredenburg and others. This work has been done by Babu Bankim Behari Gupta under the Curator's supervision.

General Remarks.

18. The chief point of interest in the year's work is the increase in analyses and determinative work, which was nearly double that of the preceding year. The Curator has had in consequence to devote a greater portion of his time to the Laboratory. Every effort has, nevertheless, been made to proceed with the work of rearrangement of the geological galleries, and it is hoped that in the present year time may be found to bring out catalogues of the Indian collections in the Fossil Gallery.

PALÆONTOLOGY.

19. In addition to the examination of specimens sent to the Department for identification, Mr. Vredenburg has been engaged in the continuation of his work on the Tertiary mollusca of India.

Owing to the various circumstances recorded in last year's General Report, it has become necessary, as already explained, to increase the scope of the work by taking into consideration the entire Tertiary molluscan fauna of India, eocene as well as post-eocene. This will necessitate a revision of the groups already studied. The revision of the following families has now been completed: *Terebridæ*, *Pleurotomidæ*, *Conidæ*, *Olividæ*, *Harpidæ*, *Marginellidæ*, *Volutidæ*, *Mitridæ*, *Fusidæ*, *Turbinellidæ* *Chrysodomidæ*,

Strepturidæ, *Buccinidæ*, *Nassidæ*, *Muricidæ*, *Purpuridæ*, *Tritonidæ*, *Cassididæ*, *Doliidæ*, representing, therefore, all the siphonostomatous Gastropoda with the exception of the *Cypræidæ*, *Strombidæ*, *Cerithiidæ* and *Cancellariidæ*,—on the completion of which and of the Cephalopoda and Opisthobranchiata, it is hoped to begin publication in successive parts.

HIMALAYAN STRATIGRAPHY.

20. In an earlier part of this report reference has been made to Mr. Middlemiss' discovery of fossils in the Tal Series some thirty-three years ago. That discovery raised hopes that fossils might also be found in other parts of the Himalayan zone, but years passed, and, although a richly fossiliferous sequence extending from Cambrian to Tertiary had been found throughout the ranges constituting what is known as the Tibetan zone of the Himalaya, the rocks of the central zone still remained barren, and a few years ago were finally relegated by the Geological Survey to the Purana (pre-Cambrian) group of unfossiliferous sediments, the Tal series being looked upon as a sporadic outlier, possibly of the supposed younger Tibetan zone. The case for a pre-Cambrian age was ably put by the Director in the *General Report* of this Department for 1903-04[1]. He wrote: "The fossiliferous character of the strata lying on the northern (Tibetan) flanks of the crystalline axis stands in remarkable contrast to the unfossiliferous character of the beds which form the southern or Lower Himalayan zone. The persistence of the northern fossiliferous zone eastwards as far as Sikkim, now established, naturally accentuates this contrast, and increases the suspicion, which has recently been growing amongst the members of the Geological Survey, that the Lower Himalayan rocks, like those of Simla, Kumaon and Bhutan, are members of very ancient systems of sediments, all or in part pre-Cambrian, nothing other, in fact, than northerly extensions of the Vindhyan, Cuddapah and similar old systems on the Peninsula, which have been caught, like the much younger Gondwana beds of Darjeeling and Assam, in the great earthfolds that have produced the Himalayan range. That one, two or more stratigraphical stages on the south could be unfossiliferous whilst their equivalents on the north

[1] T. H. Holland : *Rec., Geol. Surv. India*, XXXII, 156 (1905).

are fossiliferous might be possible; that such an accident could be carried through every geological epoch from Cambrian to Cretaceous is so highly unlikely, that we are driven to regard the ingenious and elaborate systems of lithological correspondences, which have been propounded to distribute the strata of the Lower Himalayan zone over the standard fossiliferous scale, as so much misdirected, though well intended, mental energy." This view met with general acceptance in India, although the subsequent work of Mr. Middlemiss in Kashmir, particularly in the Pir Panjal, again gave rise to doubts, and there were indications of a tendency for the balance to swing back once more towards the older view. This tendency has recently been augmented by the discovery[1], by Babu Hem Chandra Das Gupta, M.A., Demonstrator of Geology at the Presidency College, Calcutta, of fossils amongst rocks hitherto regarded as of infra-Krol age. In the summer of last year, Mr. Das Gupta took some of his students on a geological excursion to Solon, where they spent some time in a careful examination of the rocks of that neighbourhood. Mr. Das Gupta's diligence was ultimately rewarded by the discovery, near the head of the Blaini river, of a band of limestone containing a few poorly preserved fossils, one of which he regards as a *Chonetes* allied to a Permo-Carboniferous form. If this determination is correct, it will furnish important evidence in favour of the old correlation which was based on purely lithological grounds. Unfortunately, however, the fossils are fragmentary and badly preserved; the correctness of their determination as Palæozoic brachiopods, while appearing probable, is by no means entirely convincing, and the possibility of the limestone being an outlier of the patch of Subathu rocks in the immediate neighbourhood cannot yet be entirely excluded. Until clearer evidence has been obtained therefore, any modification of the accepted classification of the Lower Himalayan rocks would be premature; but the matter will be taken up as soon as occasion offers. The most hopeful solution of the problem would seem to lie in attempting to trace the Pir Panjal systems, of which the age is now known, into the Simla region; but, in the meantime, further search amongst the limestones of the Krol and Boj mountains may yield more palæontological evidence.

[1] Recorded in a paper by Messrs. E. Vredenburg and H. C. Das Gupta read at the Indian Science Congress, Lahore, in January, 1918.

ECONOMIC ENQUIRIES.

Antimony.

Amherst.

21. Mr. A. M. Heron's services were temporarily withdrawn from Tavoy for the examination of stibnite deposits at Thabyu (Amherst district) within a few miles of the Siam frontier. The locality is unfortunately very inaccessible, but Mr. Heron saw several lodes, and the quantity of ore seems to be considerable. In spite of the inaccessibility of the locality and the consequent difficulty of transport and of labour, Mr. Heron considers that the property offers a reasonable prospect of remunerative working.

Southern Shan States.

22. It was also proposed to examine the old workings for antimony known to exist in Mong Hsu estate in the Southern Shan States, and Mr. H. C. Jones was selected to undertake the investigation. Other work, however, prevented his taking this up before the end of the period under review.

Bauxite.

23. Bauxite of high quality has long been known to occur on the laterite plateaux in the western parts of Chota Nagpur and in Sarguja, and information recently obtained pointed to the possibility of its occurrence in quantities and under conditions likely to make it of economic value. It was, therefore, decided to make a survey of those plateaux during the field-season 1917-18, and the work was entrusted to Mr. C. S. Fox, who reports that bauxite of excellent quality exists in Western Chota Nagpur and in Sarguja though the occurrences are local and not of large extent. The most favourable places appear to be the cliff margins of the smaller isolated plateaux or the neighbourhood of gentle stream courses on the larger plateaux (*e.g.*, Netarhat). Invariably the rich grey deposit passes down gradually into a poor ferruginous laterite, but is abruptly covered above by a thin covering (the 'cuirasse de fer' of Lacroix) of pisolitic limonitic laterite. Mr. Fox considers it also almost certain that the rock laterite is everywhere underlain by chocolate or cream-coloured clays or kaolin, and he believes that the laterite was formed chiefly as the result of the hydration of basaltic lava flows of Deccan trap age. Trap flows

are seen on the Main *pát* (plateau) of Sarguja and embedded boulders *in situ* are common in Chota Nagpur.

Mica.

24. Owing to the great demand for mica for munitions purposes India has been called upon for a largely increased output and every effort is being made to meet the requirements of the Ministry of Munitions. With this object in view exports of mica from British India, elsewhere than to the United Kingdom, were prohibited in September 1915. This measure was not however sufficient in itself to stimulate production and shipments or to ensure the careful selection and grading of Government standard mica. In May 1916 a Government agency was organised for the purchase at fixed rates of all mica suitable for munitions purposes. Finally in March 1917 it was found desirable to improve the system still further. Prices had meanwhile risen in the London market and free export to that market was again permitted without the intervention of the Government agent whose activities were then confined to the requisitioning of stocks unreasonably withheld upcountry. Protracted rains accounted for a serious falling off in the output but shipments have steadily increased with advance of the cold weather.

25. Attention has also been paid to the geological side of the industry, and members of the Geological Survey have been engaged for some months past in giving technical advice and assistance in established mining areas and also in searching for new sources of supply. In Bihar and Orissa, Dr. L. L. Fermor and Mr. H. Walker have examined the pegmatites of Sambalpur, Angul and Dhenkanal, while Mr. G. H. Tipper has devoted his attention to Kodarma and neighbouring areas. With the sanction of the Durbar, Mr. H. C. Jones visited Udaipur and examined the belt of pegmatite-bearing schists and granites known to run through that State. He found that the pegmatites in the neighbourhood of Nansa, a few miles north of Gangapur, offered very favourable prospects, and Lieutenant Colin Campbell, whose services have been temporarily transferred to the Geological Survey by the military authorities, was sent there to prospect; Mr. Campbell fully confirmed Mr. Jones' views and found a large number of promising veins containing ruby mica of unusually high average quality. The matter was brought to the notice of the Udaipur Durbar, and negotiations are in progress for the opening up of the deposits.

Molybdenite.

26. The investigations undertaken by Mr. Walker with regard to the occurrence of molybdenite in the Madras Presidency have already been referred to in the General Report for last year. Work was continued by Mr. Walker in Madura district and subsequently in the Kadavur zemindary where wolfram was also reported to have been found. After an exhaustive search, however, Mr. Walker was unable to find any molybdenite of value or any wolfram at all.

Petroleum.

27. Dr. Pascoe resumed his investigation of the oil seepages of the Punjab. He was chiefly occupied in the geological mapping of the Chharat area westwards to join up with a similar extension of the Chak Dalla area eastwards. He found that the Chharat fold pitches and narrows two miles west of Chharat, where the Upper Nummulitic outcrop is only about 200 yards wide. Further west it widens, however, forming the Banni Fateh Khan anticline extending in a W. N. W. direction, and forking into two folds N. E. of Kutehra. The southern half forks again, both forks dying out to the north of Kutehra. The northern half runs into the boundary fault separating the Lower Nummulitics and older rocks from the Upper Nummulitics and younger formations. No oil seepages are reported from the Banni Fateh Khan area.

The Chak Dalla, or Kala Chitta, area lies on the northern side of the boundary fault and includes rocks of Lower Nummulitic, Jurassic and Triassic age, thrown into a series of tightly packed isoclinal folds. Dr. Pascoe finds that there are five principal folds occupying the Kala Chitta Hills, one of them being the Chak Dalla anticline. This anticline, west of Chak Dalla itself, becomes very complex in structure, but in the neighbourhood of the oil seepages is an overfolded isocline, the overfolding taking place towards the south. The oil comes from near the base of the Lower Nummulitic, a different horizon from that of other Punjab seepages, but is very small in quantity. During the dry season the indications consist only of bituminous earth, in small quantities; they are regarded by Dr. Pascoe as of no economic value.

28. The only other new locality visited by Dr. Pascoe was Dhulian, S. W. of the Khaur oilfield. This area consists of a large flat dome in which the same rocks as those of Khaur are

exposed. The presence of oil at reasonable depths would seem to depend on the extent to which migration has taken place from the Nummulitic series into the Murree beds.

Potash Salts.

29. Dr. M. Stuart completed his work in the Salt Range and neighbouring areas by an exhaustive investigation of the salt quarries of Bahadur Khel in Kohat district, where he found no trace of potash salts. On his return to headquarters, he submitted a full report of the results of his investigations. His views have already been summarised in the General Report of this Department for 1916, and it is now only necessary to add his conclusions as to the probable economic value of the respective areas examined.

30. As indicated in last year's report, Dr. Stuart believes that the salt was deposited originally in corresponding zones to those recognised by Bischof at Stassfurt. The three lowest of the Indian zones he names, in descending order :—

(3) the Khewra zone,
(2) the Warcha zone,
and (1) the Kohat zone.

The fourth or uppermost zone corresponding to the carnallite zone of Stassfurt has not been recognised and Dr. Stuart suggests that it may have been removed by overthrust. So far as the other three zones are concerned, the Kohat zone contains no potash salts except at Nandrakha, and Kalabagh, where, however, only traces of potash were found. Dr. Stuart considers, therefore, that the salt to the west of the Indus does not contain potash on a commercial scale.

31. Potash was found in the Warcha mine in the cis-Indus Salt Range, where there is a seam of some thickness; but it thins out to the deep. Traces of potash, however, were found in other parts of the mine, and Dr. Stuart recommends that either exploratory shafts or borings should be put down with a view to further tests.

32. At Nurpur, where a certain amount of potash salt has been excavated, the potash-bearing seams are very irregular and extremely difficult to work. The beds exposed in the ravine were exhaustively examined, but no appreciable quantities of potash were found in them.

33. The potash of the Khewra mine has already been referred to in previous reports. Dr. Stuart did not attempt further

prospecting, but suggests that it would be advisable to put down a boring at the northern end of the Khewra glen with a view to cutting through higher layers of the salt than have been expo ed in the Mayo mine.

34. On the whole, Dr. Stuart believes that, although a certain amount of potash will always be found both in the Khewra and Warcha zones, the present distribution, which he regards as due to foliation, is so irregular that no continuous bed of potash is likely to be found anywhere throughout the Salt Range. He believes that the salt which, with its potash, was orginally deposited in stratified beds, has been sheared obliquely to its bedding planes and has thus been converted into a foliated metamorphic rock. He argues that the result of this will be the occurrence of bands or lenticles of potash which may thicken out abruptly here and there, but will never be continuous for any great distances, and he considers that the recovery of potash salts in the Salt Range can only be profitable as a bye-product of salt-mining. Although Dr. Stuart's theoretical deductions as to the tectonic conditions of the salt beds are still the subject of controversy, his conclusions regarding the economic possibilities seem to be the inevitable outcome of the results of his prospecting operations.

Sulphur.

35. On the re-transfer of his services to the Geological Survey from military employ, Dr. G. E. Pilgrim was engaged in geological work in the Persian Gulf, and visited the old sulphur mines at Lingah and Bostanah. The results of his investigations are not yet available.

Tungsten.

36. The Geological Survey party continued its work in Tavoy, and Messrs. Brown and Heron were employed in the same manner as during the previous year. The output of wolfram again rose very considerably, exports having amounted to nearly 5,000 tons, while in Tavoy alone, there was an increase of 20 per cent in the output, which amounted to 3,653½ tons as against 3,034 in 1916. Attention has been drawn to two new areas during the year,—Pe in the southern part of Tavoy district and Zimba in the north. Although the prospects in Pe are promising, not much work has yet been done in that

Tavoy.

area, nor has any appreciable quantity of wolfram been extracted from Zimba, but the latter area is regarded as extremely promising in spite of great difficulties in the matter of labour and transport.

37. The small laboratory which was established by the Geological Survey at Tavoy in 1916 has now been closed the demand for assays having practically ceased to exist. The officers of the Tavoy party, however, still continue to make qualitative determinations of rocks and minerals for members of the mining community.

Singhbhum.

38. The discovery of wolfram near Kalimati station on the Bengal-Nagpur Railway was recorded during the year, and a few tons of ore have been extracted. It is proposed that, during the early part of the year 1918, Dr. L. L. Fermor should visit this occurrence with a view to investigating its probable extent and capacity.

Rajputana.

39. The Degana mine is still being worked by Mr. Pearson in co-operation with Messrs. Rolfe, Morris & Co., but the output is small. This is largely due to the complete absence of water and the consequent impossibility of introducing any methods of sluicing. A certain amount of detrital material has been worked over, however, and wolfram extracted from it by sifting. This, however, is a very unsatisfactory method as compared with sluicing.

Water.

Bandar Abbas.

40. During October and November, 1917, Dr. G. E. Pilgrim made an exhaustive investigation into the possibilities of a subterranean water-supply for Bandar Abbas on the Persian Gulf. He was able to make recommendations which will probably secure a sufficient supply to meet present requirements.

GEOLOGICAL SURVEYS.

Rajputana.

41. Owing to the many important and urgent investigations required in connection with the supply of minerals for purposes of the war, systematic survey operations were almost entirely suspended during the year under review. Mr. N. D. Daru completed his work in Jaisalmer State. This has already been referred to in the General Report for 1916.

Central Provinces.

Mr. K. A. K. Hallowes was employed in mapping the alluvium of the Wainganga river.

Burma, Putao.

42. Dr. M. Stuart was employed in a geological and mineral survey of the district of Putao in Northern Burma. He was chiefly engaged in investigating the old lead slags said to occur in very large quantities in that district. He found, however, that the quantity was not so great as has previously been supposed.

Tavoy.

43. The Tavoy party continued the geological survey of that district. Owing to the necessity for his remaining in close touch with the Deputy Commissioner and the mining community, it was impossible for Mr. Brown to take any active part in this work. It continued however, to be under his general supervision, while Mr. Heron and Messrs. Sethu Rama Rau and Vinayak Rao remained in the field throughout the working season. Practically the whole district of Tavoy has now been surveyed geologically, with the exception of certain areas for which topographical maps are not yet obtainable; the Ban-Tenasserim region and the Coastal Range also still remain to be surveyed. In his report on the operations of his party, Mr. Brown draws my attention to the great difficulties encountered in the course of the survey. With reference to certain parts, he says, "there are few villages and practically no roads. Transport is almost impossible to obtain, and then only at exorbitant rates while work is made difficult by dense forest growth. The difficulties of the country make it essential to travel with the smallest possible amount of kit, and the way in which Mr. Heron and the two Sub-Assistants have cheerfully faced fatigue and exposure. even at the risk of health, in order to complete the systematic survey of Tavoy, deserves high commendation."

The above picture of the country in which field-work has recently been in progress is no exaggeration and the work of the past three years reflects great credit on all members of the party.

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THE CASSITERITE DEPOSITS OF TAVOY. BY J. COGGIN BROWN, M.SC., M.INST.M.M., M.I.M.E., F.G.S., *Assistant Superintendent, Geological Survey of India.*

Introduction.

IN a paper submitted to the Geological Section of the Indian Science Congress in 1916, I discussed the origin of the wolfram and cassiterite-bearing quartz lodes of the Tavoy district in Lower Burma, one of the more important wolfram mining centres of the world. It was pointed out therein that the sedimentary rocks of the Mergui Series, which form the greater part of Southern Tenasserim, have been pierced by great intrusions of acid granites, and that the final phases of the intrusions were distinguished by the formation of pegmatites, aplites, quartz lodes and segregations, greisens and quartz porphyries, possessing a roughly peripheral disposition around the parent masses. The granites contain cassiterite, wolfram and molybdenite as accessory minerals The pegmatite veins and quartz lodes contain wolfram, cassiterite, scheelite in small quantities, native bismuth, bismuthinite and sulphides of iron, copper, arsenic, antimony, lead and zinc. Gold is found in the placer deposits of the district and probably comes from the lodes, but it has not been discovered *in situ* up to date.

At the present time the mining industry is concerned chiefly with the exploitation of the wolfram deposits both lode and detrital and the importance which this mineral, so essential in the production of munitions, has assumed, has, to some extent, overshadowed the occurrence of cassiterite and the possibilities of its extraction on a commercial scale. It is the object of this paper to bring together a few observations on the presence of tin ore in Tavoy.

History.

The date of the beginning of tin mining in Tavoy is lost in obscurity, but judging from the extent and character of the ancient workings, it must have been carried on for a very long time. An intimate acquaintance with the district leads me to conclude that the old miners removed very considerable quantities of tin-stone by ground-sluicing methods. The remains of tail-races and dumps have been found in most of the larger valleys, and modern hydraulic mining

often exposes the old pits from which the cassiterite-bearing gravels were won.

Tavoy became part of the British Empire in 1825. As early as 1836, Captain Low published a list of tin mines, and stated that they found employment for 400 Burmese during 4 months of the year.

In 1839, Dr. Helfer published the results of his travels in Ye, Tavoy and Mergui. He came across tin-stone workings 40 feet deep in the alluvium near Myitta, and discovered a cassiterite lode near Wunpo. This place is probably the modern Egani, where extensive ancient workings have been found recently.

In 1842, an anonymous writer mentioned the occurrence of cassiterite in the Talaingya and Taungbyauk chaungs.

In 1849, O'Riley published a paper dealing with the metalliferous deposits of Tenasserim in which a list of tin mines is given, including the Taungbyauk chaung, the head waters of the Tenasserim and the stream flowing into the Heinze Basin.

About this time a most interesting work appeared by Dr. Mason, one of the early American missionaries in Lower Burma. It is an encyclopædic account of the natural history of Tenasserim, with a portion devoted to geology and mineralogy. In it I have found the earliest reference to Tavoy wolfram with which I am acquainted. It also contains a brief description of certain tin mines in Mergui. According to Dr. Mason :—" Tin is abundant in the Provinces, commencing from the mountains in which Tavoy and Henzai rivers have their rise, the northern limit of tin in the Provinces, to the southern boundary of Mergui, Pakchan River. The richest locality in the province of Tavoy is nearly opposite the city of Tavoy on the eastern side of the mountains." That large quantities of tin must have been found in Tavoy three hundred years ago, we have evidence in an incidental remark of Mr. Ralph Fitch ; who, says Mr. Hough in the Moulmein chronicle, " travelled in this part of the world about the year 1586, or 1587." He says " I went from Pegu to Malacca, passing many of the sea ports of Pegu, as Martaban, the Island of Tavi whence all India is supplied with tin, Tenasserim, the Island of Junkselon, and many others."

In 1852, O'Riley appeared again with statistics of tin mining in Tavoy which were contradicted by Dr. T. Oldham, the first Director of the Geological Survey of India, who, some years previously had laid the foundations of our geological knowledge

of Tavoy and Mergui. Helfer came on the scene again in 1859, and in 1861 samples of tin ore from Heinze, Nwalabo and Khamaung-hla were displayed at an exhibition in London.

In 1905, the Golden Stream Syndicate issued its prospectus. This concern had prospecting rights over an area of 350 square miles, including most of Paungdaw and the upper Kamaungthwe valley, but its operations were unsuccessful.

It may be mentioned that during the years 1889-91, the Government of India supported three large prospecting parties to reconnoitre the Mergui district. They were under the charge of T. W. H. Hughes of the Geological Survey. It is to be regretted that Tavoy was not included in the scope of this work.

How is it that tin mining has attracted so little attention during the long period of years in which the existence of the deposits of Tavoy has been known? Many reasons can doubtless be advanced, but the greater weight must, in my opinion, be given to the following :—

(*a*) the isolation of the district,
(*b*) the lack of internal communications,
(*c*) the small population.

I am inclined to think that the tin industry, as described by the early European writers from Captain Low onwards, was already in a moribund condition, for the area covered by the old workings and the vast amount of ground that has been treated, seem to indicate a time when the population was a numerous and prosperous one. It is possible that indigenous tin mining was almost extinguished during Alompra's invasion in the middle of the 18th century. It is recorded that, after the Talaings were overthrown in the north, the Emperor marched down the mainland of Tenasserim, while his convoys sailed down the coast. Arriving at Tavoy, the expedition was delayed by the resistance of the Siamese garrison, which was at length betrayed. Owing to this event a series of massacres was commenced before which the earlier deeds of the invaders pale into insignificance ; every town southwards from Tavoy was blotted out of existence, and the inhabitants either put to the sword or sold into slavery.

In these events we may find the solution of the problem ; the local mining industry received a check from which it has never

recovered, and extensive tracts of a very fertile district were depopulated to an extent which has not been made up since.

In 1908, when Mr. J. J. A. Page, then an officer of the Geological Survey of India, commenced his enquiry into the conditions of tin mining in Tavoy, the output was barely one ton per annum. In 1909, wolfram was met with in several localities, and from that date the production of this mineral has steadily increased, the total amount produced by the district up to the present time being over 14,000 tons.

A statement is given below showing the annual production of tin ore in Tavoy from the year 1903 onwards :—

Year	AMOUNT.			
	Tons.	Cwts.	Qrs.	lbs.
1903	1	7	3	6
1904	1	16	0	25
1905	1	10	1	22
1906	1	5	2	0¾
1907	0	12	0	12
1908	1	10	0	8
1909	0	5	3	21
1910	0	6	0	3
1911		*Nil*		
1912	60	9	3	0
1913	64	0	3	14
1914	45	9	0	0
1915	3	17	2	20
1916	39	9	3	8
1917	125	7	2	13½

Occurrence.

Cassiterite is found in Tavoy in lodes, in detrital deposits, in placer deposits and as an original accessory in certain granites.

Lodes.

Cassiterite is almost always found in close association with wolfram. Only one instance is known of a cassiterite-quartz lode which contains no wolfram. Examples of quartz lodes containing wolfram to the almost total exclusion of cassiterite are commoner, but, as a general rule most of the Tavoy wolfrám lodes contain some cassiterite. This mineral tends to rise in quantity in certain well-marked zones. For example the ores of the lodes in the granite of the northern extension of the Paungdaw-Wagon intrusion, are very "tinny" and the proportion of tin oxide in the mixed concentrates may rise as high as 25 per cent. Cassiterite is present in relatively larger amounts in lodes traversing granite than in others which pierce sedimentary rocks, though there are exceptions to this rule. Some of the mixed lodes are of simple pegmatitic origin while others are of hydrothermal and pneumatolytic genesis. The associated minerals are nearly all micas with sulphides of iron, copper, molybdenum, lead, bismuth or zinc, the iron sulphides vastly predominating; small quantities of fluorspar also occur. Specimens have been collected which show that in some lodes the tin mineral was the first to be deposited, the tungsten compound coming second, but this is very rare; in most examples tin has clearly followed tungsten.

Greisens carrying both wolfram and cassiterite frequently border the mixed lodes when they traverse granite. They furnish a certain proportion of concentrate. Cassiterite tends to be more widely disseminated in the greisens than wolfram.

The lodes are worked by open cast and underground methods and practically the whole of the concentrates are recovered by the primitive and wasteful processes of "cobbing and panning." It is impossible to separate wolfram and cassiterite by mechanical methods, and up to very recent times the mixed ore was shipped as such. The installation of a magnetic separator in Tavoy has resulted in a portion of the mixed concentrates being separated before shipment. The rise in the production figures for tin ore during 1917 is due partly to this cause. Most of the tin ore raised in Tavoy is sent to the Federated Malay States for smelting.

It is often asserted by mining engineers that the wolfram-cassiterite lodes of Tavoy will tend to become richer in cassiterite as greater depths are attained in mining them. Whatever theoretical grounds there may be for this assumption, I am not aware of any field evidence which tends to confirm it at present.

Detrital deposits.

The larger proportion of the mixed concentrates of Tavoy are won from the detrital deposits of the hill-sides during the rainy season. In a country of such exceptional denudation it is only natural to expect the lodes to disintegrate quickly and to shed their metallic contents into the soil. True eluvial deposits are found on the hillsides in which the lodes crop out, and the minerals are washed out by streamlets into the main arteries of surface drainage during rain storms. Working from these the prospector can locate with ease the areas occupied by the mineral-bearing ground, which are often of considerable extent, and tend to become richer as the parent lodes are approached. Stones and boulders are very common in these detrital or eluvial deposits and often make up a large percentage of the total ground.

They are exploited by hydraulic methods of various kinds. If the location is suitable, water is led on to the ground by ditches or flumes; after breaking down the ground, the minerals are recovered in tail races or boxes. Should no natural water supply be available, it is often found profitable to raise water from a neighbouring stream by the aid of pumping machinery, or even, in cases of exceptionally rich ground, to excavate it by hand and transport it down hill to a water supply. The most efficient and cheapest method of working is to break down the deposit by water under high pressure discharged from a monitor. Several installations of this type are now at work in the district.

The amount of cassiterite found in eluvial deposits depends to a large extent on two factors :—

(*a*) the amount of the mineral present in the neighbouring lodes,

(*b*) the distance of the deposit from the parent lodes.

It will be shown in a later paragraph that wolfram does not travel far when compared with tin-stone.

Placer deposits.

Wolfram is never found in true placer deposits, although a contrary opinion has often been advanced. It may reach the foot of the hill-sides where the eluvial deposits of the slopes merge into the water-sorted ground filling the valley bottoms. When wolfram and cassiterite are broken out of a lode by the action of the weather and begin to travel downhill, the wolfram disappears long before its journey

is ended, whereas the tin-stone continues, and is preserved eventually in the alluvial deposits of the valley. The only wolfram ever seen in placers occurs tightly enclosed in unfractured quartz to which it owes its preservation. Chemical analysis of the tin ore obtained by dredging in Tavoy reveals as a rule, less than 0·25 per cent. of WO_3, though the detrital deposits of the slopes from which the placers are derived would probably show more wolfram than cassiterite. Wolfram possesses a very perfect cleavage, which results in its rapid comminution on movement, and the production of a fine-grained form eminently suitable for the chemical action of the various solvents it meets with during its passage through the soil. In this respect it resembles molybdenite. The only mineral of commercial importance in the placers of Tavoy is cassiterite.

Recent deposits Tavoy district.

Recent deposits in Tavoy include the modern alluvium which forms the paddy plains, the islands of the tidal rivers and the swamps along their banks, the modern laterites and lithomarges, the sands of a rapidly falling coast and the wolfram and cassiterite-bearing detrital deposits of the hill-sides. In some of the smaller valleys, the modern alluvium is being derived partly from a re-assortment of the older alluvial deposits.

Sub-recent or Late Tertiary deposits.

The sub-recent or late Tertiary deposits are of great extent and importance, for it is in them that the richer cassiterite placers are likely to occur. They are found as river-terraces raised above the present level of the inland streams; as lacustrine and fluvio-lacustrine deposits laid down in the still waters of the Myitta and other lakes; as deep eluvio-alluvial beds in the submerged basin of Kanbauk and other places; as clay banks containing the remains of marine animals, and now found raised above the level of the sea in the vicinity of Tavoy estuary.

There is abundant evidence in the district of wide-spread secular movements, and while the full sequence of these events has still to be worked out, evidence is not wanting to show that there has been a general depression of the coast-line and interior. I agree with Mr. Heron that the interior regions appear to have undergone a more recent uplift as well. The deposits of the Kanbauk area were accumulated in a rapidly sinking valley which must have stood at a comparatively higher level at one time than it does to-day.

The valley is narrow and there has been an intermingling of the eluvial deposits of the steep hill-sides with the true river alluvium; as a consequence both cassiterite and wolfram are found in them.

The deposits of the Myitta valley must have been laid down under fluvio-lacustrine conditions. The changes in the level of the land interfered with the drainage of the main branches of the Upper Tenasserim, the Kamaungthwe and the Ban Chaung, the flow of these streams was prevented and large sheets of water must have slowly accumulated; deposition became the rule where erosion is taking place to-day. At the same time the lakes became rapidly filled in with the material washed down by innumerable streams from the steep slopes surrounding them. Some of these streams drain granite country and cross the contact of the granite with the Mergui sedimentary rocks. Mineral-bearing lodes yielded their metallic contents; the wolfram and molybdenite were dissolved and lost; the resistant cassiterite was carried down and deposited in the sands and gravels at the edges of the lakes. To-day the streams are cutting into the older deposits owing to recent uplift. The Myitta lake is typical of others, though it seems to have been the largest one. Similar conditions prevailed in the Zimba and other valleys tributary to Tavoy river.

The beds as exposed in the Myitta valley consist of pebble banks and gravels loosely cemented together, of soft shales and sand rock. Interbedded with them are thin seams of lignite and rare pieces of silicified wood. The lignite is of no economic importance. (The coal of the Tenasserim valley in Mergui perhaps was formed about the same time under much the same conditions). The deposits of the Myitta valley cover scores of square miles. They certainly attain a maximum depth of 50 feet and probably more. The clay bands have a slight dip in various directions. Along the shores of the old lakes ancient stream tin workings are common, and the single tin dredge which the district possesses is operated successfully on a narrow arm of the old lake which extended up the present Hindu chaung valley.

Most of the larger streams of the district contain raised river terraces. The Pauktaing has them at Thingandon. They also occur in the Maungmeshaung, where they yield good values, and in the Kalonta, Heinze and Zimba chaungs. The Zimba deposits are said to be honeycombed with ancient workings.

Around Tavoy itself deposits of the same age are to be seen. In the river banks above the town the older clays may be observed dipping at low angles below the recent alluvium, and all the deep wells of the civil station on Tavoy hill penetrate into a stratum of gravel containing large waterworn quartz boulders, a typical sub-recent wash.

Origin of the cassiterite in the Sub-recent placers.

It has been demonstrated recently that both cassiterite and wolfram may exist as original accessory minerals in certain Tavoy granites. This is proved by panning large quantities of decomposed granite obtained *in situ.* It is possible then to have deposits containing cassiterite and wolfram, without the presence of quartz lodes, pegmatites or greisens containing these minerals. Whether such deposits can be mined profitably or not is another question which is now being studied.

One of the most important stages in the geological history of Tavoy was the exposure of the granite intrusions to denudation by the removal of their sedimentary covering, and the active erosion of the granites and their enclosed lodes. It has been shown by the Geological Survey party that the granites which are responsible for the mineralisation in Tavoy have an exceptionally uniform character over great areas. We also believe that they were formed by the same agencies at about the same period of time, and, we are faced with the problem of accounting for the fact that large expanses of them show no signs of mineralisation and contain no quartz lodes. A glance at the geological map of the district shows that all producing mines of any importance are near a granite contact, that the larger mines are located in positions where the granite bands are narrowed, that the biggest of all is situated on a very small granite exposure of its own.

My personal view is that the size of a granite exposure is some measure of the amount of erosion that it has undergone. I believe that the granite masses are roughly wedge-shaped, narrowing to the tops of the intrusions and broadening out below. The wide expanses of granite exist as such, because they have suffered severe denudation and they show no signs of lodes, because they have been cut down below the inner limit of mineralisation and any lodes that existed originally have been removed right down below their roots.

Wolfram and molybdenite in such cases have been lost, but the cassiterite is concentrated in the sub-recent placers, especially along the edges of the old lakes such as that of Myitta, which is surrounded at its northern extremity by portions of the Sinbo-Sinma granite massif, one of the largest exposures of granite in Tavoy, and also one which is unimportant from an economic point of view, for the reasons which I have advanced.

Tin-dredging and its prospects.

A cutter and suction dredge owned by Messrs. Booth and Milne, is operated successfully near Taungthonlon about 30 miles east of Tavoy on the Siam road. It excavates the old lake deposits which are situated below the modern river gravels, to a depth of 15-20 feet. Pieces of the old deposits which sometimes come through the machine consist of white clay containing a few quartz pebbles, and thickly studded with small, rounded pieces of black or brown cassiterite and fragments of topaz. Most of the ore appears to occur in a clean gravelly wash, very amenable to treatment on a dredge of this type. The deposit contains no large boulders and sunken logs are the only cause of trouble. They occur infrequently. The ore is of unusual purity. Its wolfram content is a mere fraction of 1 per cent. and is derived from small pieces enclosed in quartz. It contains small amounts of ilmenite, garnet and gold. The owners hold a lease over a large area of ground, sufficient for more extended operations and likely to last for many years to come.

I believe that there are many localities in Tavoy district where almost identical conditions occur and where there are good prospects of obtaining cassiterite in commercial quantities. The conditions prevailing in the Hindu chaung are reproduced almost exactly in numerous other valleys, and in all cases the presence of deposits profitable enough to engage the serious attention of the ancient miners is proved by the occurrence of old workings.

It is remarkable that the potentialities of some of these localities have never been investigated. I may cite the case of the Thingadon flats in the Pauktaing valley, which are crossed by the most important motor road of the district. Here there is a stream with tributaries rising in the same granite ridge, and almost in the same line as those of the Hindu chaung. Both drain identical country. Further than this, the Thingandon flats form the only natural basin of deposition in the whole course of the main stream. Old river-terraces exist and ancient workings have been traced over an area of several

thousand square feet; they are at least 20 feet deep and probably very much more extensive, being hidden by dense bamboo jungle. Cassiterite can be panned out of the stream-banks themselves, yet the area has never been properly tested by borings or pits and no one knows the depth, extent or value of the deeper-seated gravels.

The scientific investigation of tin-bearing alluvium is neither a lengthy nor an expensive process, and if it is done properly, once the ground is valued and local conditions studied in detail, definite conclusions can be arrived at as to the suitability or otherwise of the deposit for dredging. Owing to the large number of boulders which are often interspersed in the clays and pebble-beds, boring is generally out of the question. Most of the prospecting work of this nature in Tavoy will have to be done by pits, but experienced Chinese labour is available for doing this and the rates paid for sinking, which is generally done on contract, are not particularly high.

Favourable localities.

I give below a list of localities in Tavoy district, which, in my opinion, are well worth prospecting for deposits of alluvial cassiterite :—

(*a*) the Myitta valley, including the basins of the Ban and the Kamaungthwe chaungs and their tributaries, especially the Heinda, Myekhanbaw and Seinpyon chaungs ;
(*b*) the upper valley of the Kahmaunghla or Maungmeshaung chaung ;
(*c*) the country around Onhbinkwin and the Heinze Basin ;
(*d*) the gravels of the Zimba chaung ;
(*e*) the alluvial deposits in the upper portion of the Anyapya chaung and its tributaries ;
(*f*) the Thingandon flats of the Pauktaing chaung ;
(*g*) the placer deposits in the vicinity of the Heinze chaung ;
(*h*) the alluvial deposits of the Taungbyauk chaung.

LES ECHINIDES DES "BAGH BEDS" PAR R. FOURTAU (Planches 1, 2).[1]

Grâce à l'obligeante intervention du Dr. W. F. Hume, Directeur du Geological Survey of Egypt, M. Hayden, Directeur du Geological Survey of India, a bien voulu m'envoyer en communication les échinides des "Bagh Beds" faisant partie des collections de son service conservées au Musée de Calcutta. Ces échinides avaient jadis été étudiés par le prof. P. Martin Duncan[2] qui avait conclu de leur étude que les couches où ils avaient été recueillis étaient cénomaniennes, et comme les "Bagh Beds" renferment en dehors de ces échinides peu de fossiles déterminables, on a admis jusqu'à ce jour qu'ils étaient cénomaniens.

Or, parmi les formes citées par Duncan, il en était deux qui m'intriguaient énormément: *Salenia Fraasi* Cotteau et *Echinobrissus Goybeti* Cotteau dont les types proviennent du Liban, mais se trouvent, en réalité, dans des couches plus anciennes que le Cénomanien et que les découvertes récentes du R-P.Zumoffen, professeur de physique à l'Université St. Joseph de Beyrouth, ont permis de synchroniser avec l'Aptien du pourtour de la Méditerranée occidentale. Si donc, il s'agissait véritablement des deux types syriens, les "Bagh Beds" ne pouvaient plus être considérés comme cénomaniens ou, du moins, l'on pouvait émettre un doute sur les conclusions stratigraphiques du savant échinologiste anglais, conclusions qui ne concordaient guère avec la thèse soutenue quelques années auparavant par l'un des explorateurs de ces régions, M. P. N. Bose.

Je n'ai pas ici à apprécier les arguments émis au cours d'une discussion qui remonte déjà à bien des années; mais je tiens d'ores et déjà à déclarer que si, au point de vue paléontologique, je n'ai pu me rallier aux assimilations proposées par Duncan, je demeure comme lui convaincu que les "Bagh Beds" forment un ensemble

[1] This paper by M. R. Fourtau, Palæontologist, Geological Survey of Egypt, was received in June, 1914, but its publication has been delayed until now owing to the difficulties attendant on the preparation of the plates in Paris.—EDITOR.

[2] P. Martin Duncan.—Note on the Echinoidea of the cretaceous series of the Lower Narbada Valley with remarks upon their geological age. *Records of the Geol. Survey of India*, Vol. XX, pp. 81-92, et 1 pl. non numérotée.

bien défini de formations appartenant à une seule époque géologique.

Les divergences que l'on peut constater entre les résultats de mon étude et les assimilations proposées par Duncan ne sont pas au fond aussi grandes que l'on pourrait le croire au premier abord; elles proviennent simplement de ce fait que Duncan doit avoir voulu maintenir ses premières conclusions faites pour la Société Géologique de Londres[1] a une époque où les savantes recherches de Cotteau, Peron et Gauthier sur les Échinides fossiles de l'Algérie n'avaient point encore été publiées et, surtout, de la conception que l'on avait en ce temps là de l'espèce géologique, conception contre laquelle Duncan s'est toujours efforcé de réagir. Il est allé un peu trop loin dans cette réaction et les conclusions de son étude des Échinides des "Bagh Beds" en sont une preuve de plus.

Il est évidemment des formes banales que l'on rencontre un peu partout; mais, même dans ces formes que l'on trouve sur une aire géographique très étendue, l'on peut constater des différences constantes justifiant la création d'une variété ou d'une race. En tout cas, quelque soit le sort qu'auront les conclusions de mon étude paléontologique, j'estimerai avoir fait œuvre utile en indiquant les affinités des Echinides des "Bagh Beds" avec des formes depuis longtemps décrites et auxquelles Duncan ne les a pas comparés, persuadé qu'il était d'avoir affaire à une faune incontestablement cénomanienne.

DOROCIDARIS NAMADICA,[2] Duncan, 1887.

(Pl. 1, fig. 1, 2.)

Syn.: 1887 *Cidaris namadicus* Duncan (*Rec.*, *G. S. I.* p. 87, pl. sans No., fig. 1-3).

Dimensions.—J'ai sous les yeux des fragments considérables de cette belle forme; ce sont ceux qui ont été étudiés et décrits par Duncan lui-même ainsi que deux autres recueillis depuis. Il m'est cependant impossible de donner des mensurations exactes du test

[1] P. Martin Duncan.—Description of the Echinodermata from the strata on the South-East coast of Arabia and Bagh on the Nerbudda. *Quart. Journ. Geol. Soc.*, XXI, p. 348. Duncan ne paraît cependant pas s'être trop préoccupé de cette publication car il n'en parle point dans la synonymie des espèces citées dans le travail de 1887.

[2] Le mot *Cidaris* et ses composés étant féminins, j'écris *namadica* et non *namadicus* comme a écrit Duncan.

en m'aidant de tous les fragments que j'ai à ma disposition; aussi ne doit-on considérer les dimensions indiquées par Duncan que comme des approximations très près de la réalité. Autant que l'on peut s'en rendre compte, le rapport de la hauteur au diamètre du test varie entre 0·70 et 0·85 suivant la taille de l'animal.

Test atteignant d'assez grandes dimensions, proportionellement très élevé.

Ambulacres étroits, flexueux, à zones porifères très déprimées. Zones porifères formées de paires nombreuses, serrées et légèrement obliques de pores ovales acuminés en dedans, séparés par un renflement granuliforme qui se rattache par sa partie supérieure à une petite côte transversale séparant les paires de pores, et laisse entre la côte précédente et sa partie inférieure un espace libre et déprimé où passe le sillon d'un filet nerveux partant du pore interne et allant dans l'interambulacre voisin. Espace interzonaire garni de quatre rangées des petits granules mamelonés dont les deux internes n'atteignent ni le périprocte ni l'apex; à l'ambitus, on aperçoit sur les grands exemplaires quelques petites verrues microscopiques disséminées çà et là entre les granules des rangées internes. Ces granules sont généralement un peu plus petits que ceux des rangées externes; sur un grand specimen, cependant, ils sont un peu plus développés.

Interambulacres portant deux rangées de plaques coronales devenant de plus en plus hautes à mesure qu'elles s'approchent de l'apex. Tubercules principaux peu élevés, perforés, incrénelés, et entourés d'un scrobicule légèrement creusé. Dans chaque interambulacre une des plaques coronales périapicales porte un tubercule semi atrophié, représenté par un gros granule mamelonó et entouré d'un scrobicule rudimentaire.

Cercles scrobiculaires tangents entre eux à la face inférieure et à l'ambitus, s'arrondissant cependant assez rapidement; au dessus de l'ambitus ils sont nettement séparés et circulaires. Ces cercles sont formés de granules mamelonés, placés sur des socles allongés à l'angle extérieur desquels viennent s'intercaler de gros granules piriformes qui n'atteignent cependant pas le scrobicule. Zones miliaires adambulacraires pratiquement nulles. Zone miliaire médiane à peu près nulle près du péristome, puis s'élargissant peu à peu en remontant vers l'apex tout en restant toujours étroite; elle est ornée de granules serrés, aplatis, inégaux et d'autant plus petits qu'ils s'approchent de la suture médiane, paraissant vague-

ment sériés sur les plaques bien préservées. Les plaques usées par l'érosion laissent voir de nombreux sillons nerveux séparant les rangées horizontales.

Les sutures horizontales des plaques sont très nettes et paraissent munies de fossettes par suite de la hauteur des cercles scrobiculaires. La suture médiane est très déprimée et aux angles des sutures horizontales cette dépression s'accentue faisant croire à l'existence d'une fossette punctiforme, mais sur les parties bien conservées du test on s'aperçoit que cette dépression est couverte de granules miliaires.

Rapports et Différences.—Duncan n'admettait aucun démembrement du genre *Cidaris;* il n'en est plus de même aujourd'hui. Par ses tubercules principaux incrénelés, par ses zones porifères à pores non conjugués, par la suture médiane déprimée de ses interambulacres, par la disposition des filets nerveux sur le test, et enfin par l'absence de véritables fossettes aux sutures de ses plaques coronales, la forme des Bagh Beds est un véritable *Dorocidaris* Al. Agassiz.

Duncan l'a uniquement comparée au *Typocidaris cenomanensis* Cotteau et l'en a distinguée par ses tubercules principaux plus nombreux, par sa suture médiane plus déprimée et par la granulation plus grossière de sa zone miliaire, différences auxquelles il faut ajouter l'absence de fossettes suturales.

Mais, il n'est pas inutile de la comparer à certain autres *Cidaridæ* crétaciques dont elle est assez voisine.

Cidaris pretiosa Desor est moins haut, ses tubercules principaux sont moins nombreux et ils ont des cercles scrobiculaires plus petits et moins tangents entre eux, la zone miliaire médiane des interambulacres est plus large et leurs zones miliaires adambulacraires sont plus étendues; on ne peut nier cependant qu'il n'y ait beaucoup de ressemblance dans la forme et l'ornementation des ambulacres de ces deux formes, surtout si l'on considère le spécimen indien dont les ambulacres ont les granules des rangées internes plus développés que ceux des rangées externes ce qui est une des principales caractéristiques du *C. pretiosa. C. pyrenaica* Cotteau est aussi très voisin; je n'ai pas en main les matériaux suffisants pour vérifier si, comme l'affirme de Loriol,[1] *C. pyrenaica* doit être réuni au *C. pretiosa*, en tout cas les mêmes différences le séparent du *Dor. namadica.*

[1] Cf. de Loriol.—Echinologie helvétique, Ter. cré. p. 27.

Typocidaris malum A. Gras est proportionnellement aussi haut que le jeune spécimen des Bagh Beds; mais ses ambulacres sont moin sinueux et leur espace interzonaire est orné de rangées de granules plus nombreuses, les tubercules principaux sont moins nombreux par série et leurs cercles scrobiculaires sont plus petits, les zones miliaires sont incomparablement plus étendues et l'on observe des fossettes très distinctes sur les sutures des plaques coronales.

Dorocidaris Jullieni Gauthier ne s'en distingue guère que par l'ornementation plus abondante et toute différente de l'espace interzonaire de ses ambulacres et par la granulation plus fine des zones miliaires de ses interambulacres. *Dor. Thieryi* Lambert a des ambulacres moins sinueux, son test est beaucoup plus déprimé, les zones miliaires de ses interambulacres sont plus étendues et les cercles scrobiculaires de ses tubercules principaux sont tout différents. *Dor. rhotomagensis* Cotteau a également un test plus déprimé, l'espace interzonaire de ses ambulacres compte un plus grand nombre de rangées de granules, les zones miliaires de ses interambulacres sont plus étendues et ses plaques coronales sont beaucoup plus basses.

En somme *Dor. namadica* présente les plus étroites affinités avec le *Dor. Jullieni* de l'Aptien d'Algérie et ces deux formes paraissent dériver du *C. pretiosa.*

Collection du Geological Survey of India. Bagh Beds: 4 fragments de test Nos. 4/298, 4/299 et 4/300. Lower Nerbudda: 2 fragments No. $\frac{K.1}{311}$.

SALENIA KEATINGEI R. Fourtau.

(Pl. 1, fig. 3.)

Syn.: 1887 *Salenia Fraasi* Duncan non Cotteau (*Records, G. S. I.*, p. 90).

Dimensions.

Diamètre.	Hauteur.
14 mill.	8 mill.
11·5 „	6·25 „
10 „	5·75 „

Test de petite taille, circulaire. Face supérieure médiocrement renflée et légèrement subconique. Face inférieure à peu près plane, arrondie sur les bords.

Appareil apical arrondi, légèrement bombé, très large—son diamètre égale les 7/10 du diamètre du test. Les sutures des plaques sont marquées d'incisions assez nombreuses et profondes. Plaques génitales plus longues que larges, portant au milieu un pore génital bien ouvert au centre d'un léger renflement d'où partent des sillons rayonnants allant en s'élargissant et en s'approfondissant à mesure qu'ils approchent de la suture; la génitale 2 porte le madréporite dans une fissure étroite partant du pore génital et se dirigeant vers la suture de la génitale 3. Plaques ocellaires subtriangulaires, à bord externe sinueux et comme trilobé, portant des sillons moins nombreux et moins apparents que ceux des génitales et partant du lobe médian du bord externe, lobe sous lequel est placé le pore ocellaire. Plaque suranale plus large que haute, portant la même ornementation que les génitales et fortement échancrée par le périprocte qui en atteint presque le centre. Périprocte plutôt subcirculaire que subtriangulaire, un peu plus large que haut, à bords légèrement relevés au dessus de l'appareil.

Ambulacres étroits,—leur largeur est à celle des interambulacres dans le rapport de 1:3. Zones porifères légèrement onduleuses, formées de paires à peu près horizontales de petits pores ronds séparés par un renflement granuliforme. Ces paires sont directement superposées sauf près du péristome où elles semblent se multiplier sur les trois premières plaques adorales. Espace interzonaire garni de deux rangées marginales de granules mamelonés, allongés dans le sens de la hauteur, au nombre de 16-17 par série. La taille de ces granules est sensiblement la même tout le long des zones porifères sauf près de l'apex et du péristome où elle diminue un peu. Entre ces granules, on distingue, à l'ambitus, quelques petites verrues microscopiques zigzagant entre les deux rangées.

Interambulacres assez larges, portant deux rangées de 5-6 tubercules principaux crénelés, imperforés, à mamelon élevé. Les cercles scrobiculaires ne sont complets que du côté de la suture médiane comme dans tous les *Salenia* appartenant à la section des *quadratae* Arnaud. Zone miliaire médiane pratiquement nulle; à l'ambitus, il y a simplement quelques verrues microscopiques éparses sans ordre entre les deux cercles scrobiculaires.

Péristome à fleur de test, subcirculaire, de dimensions moyennes —son diamètre dépasse un peu la moitié du diamètre du test dans le plus petit spécimen (5 mill. 75) et n'atteint pas tout à fait cette moitié dans le plus grand (6 mill. 25)—à scissures branchiales très faiblement marquées.

Rapports et Différences.—Duncan a rapporté les trois spécimens que j'ai sous les yeux et qui ont été recueillis par le capitaine Keatinge, au *S. Fraasi* Cotteau. J'ai déjà montré[1] combien la diagnose exacte mais un peu vague de l'illustre échinologiste français avait causé de confusions de la part de de Loriol, de Gauthier et de moi-même; Duncan n'a pas été plus heureux que nous. L'année dernière, grâce à l'obligeance du R. P. Zumoffen, j'ai pu étudier tous les *S. Fraasi* recueillis dans le Liban sauf celui décrit par de Loriol et qui provenait du Gebel Sannin—ce spécimen recueilli dans des couches jurassiques n'a pu être retrouvé, mais ce n'est certainement pas un *S. Fraasi*—et j'ai pu constater que le *S. Fraasi* se distingue entre tous les *Salenia* connus par la proportion très élevée du rapport de la largeur de ses ambulacres à celle de ses interambulacres. Or, cette proportion qui est, en effet, de 1:4·25 chez les véritables *S. Fraasi* de l'Aptien du Liban, n'est que de 1:3 chez les *Salenia* des Bagh Beds; en outre, l'appareil apical de ces derniers est autrement sculpté et plus développé, la forme du périprocte est différente et le péristome est relativement plus étroit.

Si nous comparons maintenant les *Salenia* des Bagh Beds aux *Salenia* crétaciques de la section des *quadratae* qui s'en rapprochent le plus, nous voyons que *S. folium-querci* Desor en est assez voisin. Mais chez ce dernier les ambulacres sont un peu plus larges—le rapport de leur largeur à celle des interambulacres est de 1:2·50— et les granules de leur espace interzonaire sont moins nombreux par série, l'appareil apical est encore plus développé et marqué de sillons plus profonds qui en découpent les plaques, le péristome est relativement plus étroit et le test est plus déprimé.

S. mamillata Cotteau est une forme très rare dont le test est plus déprimé, les tubercules plus saillants et les scissures branchiales du péristome bien plus marquées.

S. prestensis Desor est au contraire plus élevé, ses ambulacres plus étroits ressemblent beaucoup à ceux du *S. Fraasi*, les tubercules

[1] R. Fourtau. Échinides Aptiens d'Égypte et de Syrie; *Bull. Inst. Égyptien*, 5e série, tome vii, p. 44.

principaux de ses interambulacres sont de taille bien moindre et leur zone miliaire est beaucoup plus large, son appareil apical est moins développé et son péristome est relativement plus étroit.

S. geometrica Agassiz est également beaucoup plus élevé, la zone miliaire de ses ambulacres est plus large, ses tubercules principaux sont plus nombreux par série et plus petits, enfin son appareil apical est moins développé et porte une ornementation beaucoup plus obsolète.

En resumé, les *Salenia* des Bagh Beds se rapprochent surtout du *S. mamillata* dont ils semblent être une mutation ou une race plus évoluée. Je les maintiens comme forme distincte en les dédiant à leur collecteur, parce que le *S. mamillata* est trop peu connu et que les différences que j'ai signalées, si elles étaient, par la suite, reconnues constantes, sont de nature à maintenir cette séparation.

Collection du Geological Survey of India, Bagh beds: 2 exemplaires No. 4/3.—Lower Nerbudda No. *K. 1.*

CYPHOSOMA NAMADICUM R. Fourtau.

(Pl. 1, fig. 4.)

Syn.: 1887 *Cyphosoma cenomanense* Duncan non Cotteau, (*Records, G. S. I., p. 89*).

Dimensions.

Diamètre.	Hauteur.
24 mill.	11·50 mill.
22 „	10·50 „
17 „	7 „

Test circulaire, parfois subpentagonal. Face supérieure médiocrement élevée et légèrement déprimée à l'apex. Face inférieure déprimée au centre, arrondie sur les bords.

Appareil apical caduc, l'empreinte qu'il a laissé est de dimensions médiocres.

Ambulacres à zones porifères légèrement onduleuses à l'ambitus; les paires de pores sont légèrement bigéminées au voisinage de l'apex et semblent se multiplier près du péristome. Tubercules ambulacraires crénelés, imperforés, assez développés à l'ambitus, diminuant de grosseur et alternant dans chaque série aux approches

de l'apex. Cercles scrobiculaires rudimentaires presque invisibles par suite de l'état des spécimens; ils étaient certainement incomplets du côté de la zone porifère et tendaient à se confondre vers la suture médiane.

Interambulacres assez larges. Tubercules principaux semblables aux tubercules ambulacraires, un peu plus gros seulement et diminuant moins rapidement de grosseur aux approches de l'ambitus. Tubercules secondaires petits mais très distincts, formant deux rangées externes situées le long des zones porifères et remontant assez haut à la face supérieure sans toutefois atteindre l'apex, et, le long de la suture médiane, deux rangées internes dont les tubercules, bien développés à la face inférieure, s'atténuent assez brusquement à l'ambitus et se perdent dans la granulation miliaire de la face supérieure. Zone miliaire médiane dénudée et très légèrement déprimée aux approches de l'apex, garnie à l'ambitus de granules assez espacés qui tendent à se confondre avec les granules des cercles scrobiculaires, et à granulation très dense à la face inférieure. Suture médiane déprimée.

Péristome relativement assez petit, subcirculaire, à scissures branchiales peu profondes, situé dans une dépression très sensible de la face inférieure.

Rapports et Différences.—Duncan tout en reconnaissant que les nombreux *Cyphosoma* des Bagh Beds n'étaient pas absolument conformes au type du *C. cenomanense* de Cotteau, les a réuni cependant à cette forme assez rare du Crétacé moyen de la Sarthe parce que, disait-il, les différences qu'il avait pu constater n'étaient pas importantes et qu'il convenait de les négliger. Pour ce savant échinologiste, deux seuls caractères suffisaient à justifier l'assimilation qu'il proposait. En effet, Duncan a dit textuellement: "The numerous vertical rows of primary tubercles at and below the ambitus, six in each interradium, and the bare median space abactinally, with slight sutural markings, readily distinguish the species." Or Cotteau n'a jamais indiqué que quatre rangées de tubercules dans les interambulacres de son *C. cenomanense*[1] et la figure 10 de la planche 1137 de la Paléontologie Française n'en montre pas davantage. Il s'en suit donc que nous ne pouvons accepter l'assimilation proposée par Duncan.

[1] Cotteau et Triger: *Echinides de la Sarthe*, p. 150, pl. XXVI, fig. 16; et Cotteau: *Paléontologie Française*, terrains crétacés, tome VII, p. 580, pl. 1137, fig. 6-13.

En outre, les oursins des Bagh Beds se distinguent du *C. cenomanense* par la plus grande hauteur proportionnelle de leur test: 0·46 au lieu de 0·38, par les paires de pores de leurs ambulacres moins fortement bigéminées aux approches de l'apex, par leurs granules miliaires plus denses à l'ambitus et à la face inférieure et qui, sur aucun des exemplaires que j'ai sous les yeux, ne prennent la forme elliptique et l'aspect rayonné signalés par Cotteau sur la plupart des *C. cenomanense*, par leur péristome plus petit et situé dans une dépression bien marquée de la face inférieure.

Par les rangées internes de tubercules secondaires de ses interambulacres, la forme indienne appartient à la section pour laquelle Pomel a proposé le nom de *Pliocyphosoma*. Il convient donc de la comparer aux formes appartenant a cette section.

C. Peroni Cotteau a une zone miliaire plus déprimée au sommet, ses tubercules secondaires sont plus nombreux et plus développés dans chaque série—il pourrait même y avoir quatre séries externes —l'empreinte laissée par son appareil apical est plus étendue et son péristome est à fleur de test.

C. Bargesi Cotteau a les paires de pores de ses ambulacres plus fortement et plus longuement bigéminées à la face supérieure, les tubercules secondaires dans les rangées internes sont plus développés au dessus de l'ambitus qu'en dessous, ses tubercules principaux et secondaires sont plus nombreux dans chaque série verticale; la granulation miliaire est plus dense; son péristome est moins enfoncé.

C. microtuberculatum Cotteau a également les paires de pores de ses ambulacres plus fortement bigéminées à la face supérieure; il a quatre séries externes de tubercules secondaires plus développés et remontant plus près de l'apex; son péristome est à fleur de test.

C. Arnaudi Cotteau est beaucoup plus haut, ses tubercules principaux et secondaires sont plus atrophiés à la face supérieure, sa zone miliaire médiane est beaucoup plus dénudée de l'ambitus à l'apex.

C. Desmoulinsi Cotteau a, par contre, une zone miliaire médiane sans aucune dénudation appréciable à la face supérieure et les rangées de ses tubercules secondaires remontent presque jusqu'à l'apex aussi bien les internes que les externes.

C. Verneuili Cotteau a six rangées de tubercules secondaires très petits.

C. libanoticum Fourtau a également six rangées de tubercules secondaires et sa granulation miliaire est beaucoup moins dense à l'ambitus et à la face inférieure.

En somme c'est encore du *C. Peroni* que se rapproche le plus la forme des Bagh Beds que je propose de nommer *C. namadicum.*

Collection du Geological Survey of India.—Bagh Beds No. 4/302.

ORTHOPSIS INDICA.[1]

Syn.: 1877 *Orthopsis indicus* Duncan, (*Records, G. S. I.*, p. 88, pl. sans No., fig. 4—8).

Je n'ai rien à ajouter à la diagnose de Duncan. Ce savant s'est borné à comparer son nouveau type à l'*O. similis* Stoliczka de l'Aryaloor Group du Sud de l'Inde et a négligé de le comparer à l'*O. Repellini* Desor dont cependant il est très proche et dont il ne se distingue en réalité que par la disposition oblique des pores dans chaque paire et par sa granulation miliaire beaucoup moins dense.

Collection du Geological Survey of India.—Bagh Beds No. 4/301.

ECHINOBRISSUS HAYDENI R. Fourtau.

(Pl. 2, fig. 1.)

Syn.: 1887 *Echinobrissus Goybeti* Duncan non Cotteau (*Records, G. S. I.*, p. 90).
1887? *Nucleolites similis* Duncan non d'Orbigny (*Records, G. S. I.*, p. 91).

Dimensions: Longueur 19 mill., largeur 17 mill., hauteur 9 mill.

Test subquadrangulaire, arrondi et légèrement rétréci en avant, à côtes presque parallèles, carrément tronqué avec une légère sinuosité médiane en arrière. Face supérieure arrondie et légèrement déclive en avant, le sommet étant en arrière de l'appareil apical au premier tiers de l'interambulacre impair, abrupte en arrière. Face inférieure pulvinée sur les bords, déprimée longitudinalement au centre.

Appareil apical excentrique en avant aux 40/100 de la longueur.

[1] La terminaison *opsis* indique le féminin et non le masculin.

Ambulacres lancéolés, très étroits et très courts, ceux du bivium un peu plus longs que ceux du trivium. Zones porifères à paires de pores inégaux, l'interne rond et l'externe linéaire, nettement conjugés sur l'exemplaire le mieux conservé. Ces caractères s'effacent à la moindre usure du test et les pores paraissent alors ronds et séparés. Espace interzonaire légèrement costulé, égalant à peine en largeur le tiers d'une zone porifère.

Périprocte dans un sillon large, à bords carénés, acuminé en haut, remontant jusqu'au premier tiers de la distance qui sépare l'appareil apical du bord postérieur et entamant légèrement mais visiblement ce dernier.

Péristome excentrique en avant, assez mal conservé sur un exemplaire, caché par une gangue très dure sur l'autre; il devait être assez ouvert, pentagonal. Le floscelle est invisible. Il n'y a pas de bande lisse sternale entre le péristome et le bord postérieur.

Tubercules principaux petits, très nombreux et nettement scrobiculés à la face supérieure, un peu plus gros et plus écartés à la face inférieure, principalement autour du péristome.

Rapports et Différences.—Duncan avait rapporté les deux plus grands spécimens à l'*E. Goybeti* Cotteau. J'ai pu examiner, grâce au R. P. Zumoffen de l'Université St. Joseph de Beyrouth, un grand nombre d'*E. Goybeti.* Cette forme est toujours de taille bien moindre, son appareil apical est subcentral et coïncide avec le sommet de la face supérieure, sa rosette ambulacraire est plus développée, le sillon anal à sommet arrondi ne remonte qu'à la moitié de la distance de l'apex au bord postérieur et n'entame pas ce dernier.

E. eddissensis Gauthier serait plus voisin de la forme indienne; il est cependant proportionnellement plus haut et plus large, le point culminant de la face supérieure coïncide avec l'apex qui est un peu moins excentrique en avant; le sillon périproctal se termine à une distance plus grande de l'appareil apical et le bord postérieur n'est pas entamé par ce sillon; en outre les ambulacres sont tous beaucoup plus longs.

E. subquadratus d'Orbigny, auquel Duncan avait primitivement, mais par erreur a-t-il dit, rattaché les deux grands spécimens des Bagh Beds, est plus étroit, le profil de sa face supérieure est plus surbaissé, son bord postérieur est plutôt rostré que tronqué, ses ambulacres sont plus allongés, son sillon périproctal est beaucoup

moins allongé et beaucoup plus éloigné de l'appareil apical. Beaucoup d'auteurs, d'ailleurs, considèrent *E. subquadratus* comme appartenant au genre *Clypeopygus* d'Orbigny.

J'ai réuni aux deux grands spécimens attribués par Duncan à l' *E. Goybeti*, deux petits *Echinobrissus* déformés par compression et dont le test est assez corrodé qu'il avait assimilés au *Nucleolites similis* d'Orbigny. Sans nul doute, dans les ambulacres du mieux conservé, on aperçoit des pores ronds et non conjugués, mais le fait se reproduit sur un des grands exemplaires qu'il a attribués à l'*E. Goybeti* et il semble que le test est aussi usé sur le grand spécimen que sur le petit. Or, Gauthier a depuis longtemps signalé la confusion que pouvait occasionner une usure même légère du test lorsqu'il s'agit de distinguer *Nucleolites* d'*Echinobrissus* et j'ai eu maintes fois l'occasion de vérifier la justesse de ses assertions. En fait, le seul caractère bien observable sur le mieux conservé de ces petits spécimens est le sillon périproctal dont la forme et les dimensions concordent avec celles que jè viens de signaler sur les deux grands spécimens attribués par Duncan à l'*E. Goybeti*; aussi je n'hésite point à réunir en une même forme que je me fais un véritable plaisir de dédier au directeur actuel du Geological Survey de l'Inde, les quatre *Echinobrissus* recueillis à ce jour dans les Bagh Beds. Et cela d'autant plus que, si les petits spécimens ont une vague ressemblance avec le type figuré par d'Orbigny[1], ils ne ressemblent point du tout au plésiotype figuré par Cotteau[2].

Collection du Geological Survey of India—Bagh Beds Nos. 4/303 et 4/304; 4 exemplaires.

HEMIASTER OLDHAMI R. Fourtau.

(Pl. 2, fig. 2, 3.)

Syn.: 1887 *Hemiaster cenomanensis* Duncan non Cotteau (*Rec., G. S. I.*, p. 91).

Dimensions.

Longueur.	Largeur.	Hauteur.
33·5 mill.	32 mill.	22 mill.
33 „	31·5 „	21 „
32 „	32 „	22 „
31 „	30 „	22 „
29 „	29 „	19 „
27 „	25 „	19 „
19·5 „	18 „	14 „

[1] d'Orbigny : Paléontologie Française, terr. crét., tome VI, pl. 958, fig. 1-4.
[2] Cotteau et Triger : *Echinides de la Sarthe*, pl. XXXII, fig. 10-13.

Test subpolygonal, presque aussi large que long et, parfois, aussi large que long; légèrement rétréci et assez fortement sinueux en avant, rétréci et tronqué carrément en arrière, ayant sa plus grande largeur aux deux cinquièmes antérieurs. Face supérieure haute, déclive d'arrière en avant, assez fortement carénée sur l'interambulacre impair. Face inférieure haute, parfois légèrement oblique, parfois verticale. Face inférieure très légèrement convexe, un peu plus bombée sous le plastron.

Appareil apical subcentral, enfoncé dans un méplat que surmontent l'extrémité des carènes interambulacraires, ethmophracte, montrant 4 pores génitaux en rectangle plus large que haut, et 5 ocellaires; l'ocellaire III pénétrant entre les génitales 2 et 3; les autres ocellaires sont aux angles extérieurs des génitales. Le madréporite est confiné sur la génitale 2 et ne sépare pas les génitales postérieures.

Ambulacre III dans un sillon assez large et peu profond, entamant cependant assez fortement l'ambitus et se continuant bien marqué à la face inférieure jusqu'au péristome. Zones porifères composées de petites paires assez espacées et obliques de pores ronds séparés par un assez fort renflement granuliforme. Le fond du sillon est garni d'une granulation assez grossière, serrée, éparse sans ordre, parmi laquelle on aperçoit çà et là de petits tubercules nettement scrobiculés. Ces tubercules forment en outre deux rangées assez régulières le long des zones porifères et augmentent de volume au fur et à mesure qu'ils approchent de l'ambitus.

Ambulacres pairs assez divergents, logés dans des sillons creusés et assez étroits, inégaux,—I et V sont d'un tiers moins longs que II et IV. Zones porifères formées de paires de pores linéaires, légèrement inégaux, et conjugués par un sillon obsolète; chaque paire est séparée de sa voisine par une bande de test relativement large et granulée. Espace interzonaire un peu moins large qu'une zone porifère et ornée de très petits granules qui s'effacent à la moindre usure du test.

Péristome réniforme, très faiblement labié, situé à peu près au quart antérieur de l'oursin mais plutôt en deçà qu'au delà.

Périprocte grand, ovale, longitudinal, légèrement acuminé aux deux extrémités, situé au sommet de la face postérieure et surmontant une aréa subtriangulaire, vaguement déprimée et circonscrite par des nodosités peu accentuées.

Fasciole péripétale bien visible, en écharpe, passant à l'extrémité des ambulacres pairs et franchissant le sillon de l'ambulacre impair immédiatement au dessus de l'ambitus, assez étroit en avant et en arrière, s'élargissant sur les flancs.

Tubercules scrobiculés, nombreux, assez gros et disséminés sans ordre à la face supérieure, un peu plus gros et serrés à l'ambitus et plus gros encore et espacés à la face inférieure, principalement aux abords du péristome. Granulation miliaire dense, donnant un aspect chagriné aux parties bien conservées du test.

Rapports et Différences.—Duncan a attribué ces *Hemiaster* à l'*H. cenomanensis* Cotteau tout en reconnaissant que les ambulacres postérieurs pairs des spécimens indiens étaient plus longs et plus étroits que ceux du type. Mais, dit-il, si l'on compte les paires de pores indiquées sur la figure de Cotteau, on constate qu'il existe le même nombre de paires dans les zones porifères des ambulacres postérieurs du type et dans celles des spécimens de l'Inde; la longueur est donc indifférente; reste l'étroitesse, et cela, dit Duncan, peut donner lieu à la création d'une variété.

J'ai, à mon tour, soigneusement compté les paires de pores sur la figure donnée par Cotteau et sur le meilleur des spécimens indiens. J'ai trouvé pour le type de la Sarthe 24 paires de pores pour l'ambulacre I, et 48 paires pour l'ambulacre II; cependant que le spécimen indien me donnait 31 paires pour l'ambulacre I, et 42 paires pour l'ambulacre II, et cela bien que le type de Cotteau soit à peu près de même taille que le spécimen indien—il est même un peu plus grand. L'*H. cenomanensis* est en outre beaucoup plus cordiforme—Cotteau dit presque carré—il est plus large en avant et moins rétréci en arrière, sa face supérieure est moins élevée, sa face inférieure est plus plate, ses tubercules sont plus rares, son fasciole péripétale est partout d'égale largeur.

Nous sommes d'ailleurs très peu fixés sur ce que peut bien être, en réalité, le véritable *H. cenomanensis* dont quelques exemplaires fort rares ont été recueillis au Mans et à Yvré l'Evêque (Sarthe). Plus tard, sans doute, on a réuni à ce type de nombreux exemplaires recueillis soit à Briolley (Maine et Loire), soit dans les Charentes, à Fouras et à Piédemont (Char. Inférieure) principalement.

Or, comme me le fait remarquer dans une de ses lettres mon excellent confrère M. J. Lambert, cette incertitude a augmentée depuis que V. Gauthier a séparé du type les *Hemiaster* de Briolley

qui sont devenus *H. Grossouvrei* Gauthier.[1] Ces oursins sont en général plus étroits et plus hauts que l'*H. cenomanensis*, leurs sillons ambulacraires sont plus étroits et leurs interambulacres portent des nodosités; mais, assure M. Lambert, ces différences ne sont pas constantes. Quelques années auparavant, Cotteau lui-même hésitait à réunir à son *H. cenomanensis* les oursins des Charentes ainsi nommés par Arnaud[2] et il déclarait qu'ils en différaient par leur forme plus épaisse et plus carrée, et par leurs ambulacres postérieurs plus longs, moins larges et moins arrondis, et que l'on pouvait se demander si ces oursins réunis à ceux de Briolley ne constituaient pas une espèce à part. Aussi suis-je de l'avis de M. Lambert que, seul, l'examen des types et de séries assez nombreuses pourrait permettre d'éclaircir cette question.

En tout état de cause, la forme indienne se distingue de l'*H. Grossouvrei* par son test plus massif, polygonal; par ses ambulacres plus développés, et par son apex subcentral. Elle peut être différenciée de la forme charentaise par son test plus élevé, polygonal, et probablement aussi par ses ambulacres plus développés.

En revanche, les spécimens indiens se rapprochent beaucoup de l'*H. Luynesi* Cotteau du Cénomanien de la Palestine. Celui-ci a cependant sa face supérieure plus horizontale, sans carène à l'interambulacre impair, tous ses ambulacres sont plus larges, plus développés et plus pétaloides. Il semble bien que cette forme soit une mutation de la forme indienne.

H. Meslei Peron et Gauthier du Cénomanien d'Algérie est beaucoup plus étroit et plus déprimé.

H. pseudofourneli Peron et Gauthier, si commun dans tout le Cénomanien du Nord de l'Afrique, est en général plus arrondi, le sillon de son ambulacre III entame beaucoup moins l'ambitus, sa vestiture est tout autre.

Collection du Geological Survey of India—Bagh Beds, No. 4/306: sept exemplaires.—Nerbudda Valley, No. $\frac{K.1}{310}$: deux exemplaires.

[1] Gauthier dans de Grossouvre ; Sur le terrain crétacé dans le Sud-Ouest du Bassin de Paris, *Bull Soc. Géol. France* (3), tome XVII, p. 526, 1889.
[2] Cotteau.—Echinides du Sud-Ouest de la France, *Ann. Soc. Sc. Naturelles*, p. 167, La Rochelle, 1883.

OPISASTER SUBSIMILIS R. Fourtau.

(Pl. 2, fig. 5.)

Syn.: 1887 *Hemiaster similis* (pars) Duncan non d'Orbigny, nec Cotteau, nec Oldham (*Rec.*, *G. S. I.*, p. 92).

Dimensions.

Longueur.	Largeur.	Hauteur.
23·5 mill.	22·4 mill.	16·5 mill.
*20·3 „	19·5 „	15 „
21 „	20 „	14 „

Test subcordiforme, un peu rétréci et légèrement sinueux en avant, un peu plus rétréci et plutôt arrondi que tronqué en arrière, ayant sa plus grande largeur à peu près à la moitié de la longueur. Face supérieure assez élevée, déclive d'arrière en avant; face postérieure obtusément tronquée; face inférieure uniformément convexe, légèrement déprimée autour du péristome.

Appareil apical subcentral ou légèrement excentrique en arrière, ethmophracte, présentant 4 pores génitaux bien ouverts en carré.

Ambulacre III dans un sillon large et peu profond, allant en s'élargissant vers l'ambitus où il ne produit qu'une faible sinuosité qui est cependant sensible, se continuant presque à fleur de test à la face inférieure jusqu'au péristome. Zones porifères composées de petites paires assez espacées de pores disposés légèrement en chevrons et séparés par un renflement granuliforme qui s'efface à la moindre usure du test. Le fond est couvert de très petits granules.

Ambulacres II et IV dans des sillons très peu creuses, flexueux, à zones porifères inégales; l'espace interzonaire est un peu plus large que la zone postérieure.

Ambulacres I et V de moitié moins longs que II et IV, presque aussi divergents mais droits.

Péristome un peu en avant du quart antérieur.

Périprocte assez grand, ovale, acuminé aux deux extrémités, presque au sommet de la face postérieure.

Fasciole peu visible par suite de l'état des spécimens; il devait être assez étroit, en écharpe.

Tubercules petits et très clairsemés à la face supérieure, un peu plus gros et un peu plus serrés à l'ambitus.

Rapports et Différences.—Duncan a rapporté à l'*H. similis* d'Orbigny les exemplaires indiens tout en constatant que certains d'entre eux pourraient constituer une espèce séparée mais fort voisine. Parmi les cinq exemplaires que m'a communiqués le Geological Survey of India, trois se séparent nettement du type de d'Orbigny et de Cotteau, dont M. Oldham a reproduit une figure dans son traité de Géologie de l'Inde.[1] En effet, le sillon de leur ambulacre impair entame légèrement mais nettement l'ambitus; les pores des zones porifères sont disposés en chevron et non pas par paires obliques; la relation de la longueur de leurs ambulacres postérieurs à celle des antérieurs pairs est de 1: 2 au lieu d'être 1: 3; ils sont proportionnellement et constamment plus déprimés que les types de d'Orbigny et de Cotteau: 0·75 au lieu de 0·80; leur face inférieure est plus uniformément convexe, leur face postérieure est plutôt arrondie que tronquée et il n'y a pas d'aréa déprimée sous le périprocte; enfin, la tuberculation est bien moins dense et non sériée à la face supérieure et c'est sur ce point qu'a insisté d'Orbigny.

Par leurs ambulacres antérieurs pairs, flexueux et à zones porifères inégales, ces oursins me paraissent se rattacher plutôt au genre *Opisaster* Pomel. L'*O. Morgani* Cotteau et Gauthier du Sénonien de Perse paraît en être le descendant et s'en distingue surtout par l'exagération des caractères que j'ai signalés dans ma diagnose ainsi que par sa taille plus déprimée.

Collection du Geological Survey of India.—Bagh Beds, No. 4/307 (pars): trois exemplaires.

OPISASTER sp. ind.

(Pl. 2, fig. 4.)

Syn.: 1887 *Hemiaster similis* (pars) Duncan non d'Orbigny nec Cotteau, nec Oldham (*Rec., G. S. I.*, p. 92).

Les deux autres exemplaires que m'a communiqués le Geological Survey of India, sous le nom d'*H. similis*, sont deux oursins globuleux un peu usés qui se distinguent des premiers par leur moindre largeur, leur pourtour ovale allongé, presque acuminé en arrière, leur sillon impair n'entamant pas le bord, leur ambulacre III à zones porifères très courtes et dont les paires de pores sont obliques,

[1] R. D. Oldham.—*Manual of the Geology of India.* Cretaceous fossils. Calcutta, 1893.

leurs ambulacres pairs plus à fleur de test et dont les antérieurs sont moins divergents et plus flexueux et dont l'apex est beaucoup plus excentrique en arrière.

Ces spécimens sont fort voisins d'une forme recueillie par Lartet à l'Est du Jourdain et qui est connue par un seul exemplaire usé et dont la position stratigraphique exacte n'a pu être déterminée, l'*H. Vignesi* Cotteau, qui paraît être un *Pliotoxaster* ou un *Opisaster*, mais qui est beaucoup plus basse, dont l'apex est encore plus excentrique en arrière et dont les ambulacres sont plus développés. La forme indienne pourrait en être également la forme ancestrale.

Collection du Geological Survey of India.—Bagh Beds, No. 4/307 (pars) : 2 exemplaires.

CONCLUSIONS.

Le tableau suivant résume les conclusions paléontologiques que je crois pouvoir tirer de l'étude des échinides des "Bagh Beds" qui m'ont été communiqués par le Geological Survey of India.

Formes indiennes.	Formes les plus voisines et niveau stratigraphique de ces formes.
Dorocidaris namadica Duncan .	*Dor. Jullieni* Gauthier, Aptien d'Algérie.
Salenia Keatingei Fourtau . .	*S. mamillata* Cotteau, Aptien de France.
Cyphosoma namadicum Fourtau .	*C. Peroni* Cotteau, Barrrémien de France et de Suisse.
Orthopsis indica Duncan . .	*O. Repellini* Desor, Barrémien et Aptien de France, Suisse, Portugal.
Echinobrissus Haydeni Fourtau .	*E. eddissensis* Gauthier, Aptien et Albien d'Algérie et Tunisie.
Hemiaster Oldhami Fourtau . .	*H. Luynesi* Cotteau, Cénomanien de Palestine.
Opisaster subsimilis Fourtau . .	*O. Morgani* Cotteau et Gauthier, du Sénonien de Perse.
Opisaster sp. ind	*O. Vignesi* Cotteau, Crétacique de la Palestine.

La majorité de ces échinides a d'incontestables affinités avec des formes éocrétaciques et les autres semblent plutôt être les ancêtres de formes mêsocrétaciques. Je crois donc pouvoir affirmer sans trop de témérité que la faune échinitique des "Bagh Beds" classe ces formations au sommet de l'éocrétacique dans L'Albien ("Gault" des auteurs anglais), étant donné que c'est à cette époque géologique qu'ont apparu les premiers *Hemiaster*.

Cette conclusion me paraît confirmée par la présence dans ces couches du *Placenticeras Mintoi* Vredenburg[1], forme voisine des *P. Uhligi* Choffat et *P. saadense* Peron et Thomas, que l'on trouve dans le Bellasien du Portugal et le Vraconnien d'Algérie et de Tunisie. Or, le Bellasien comme le Vraconnien représentent plutôt les parties moyenne et supérieure de l'Albien que le Cénomanien inférieur.

L'étude des autres fossiles de "Bagh Beds": mollusques, brachiopodes et coraux, serait intéressante à entreprendre pour la confirmation de ces conclusions stratigraphiques.

EXPLICATION DES PLANCHES.

PLANCHE 1.

1. *Dorocidaris namadica* Duncan, fragment de test (grand. naturelle).
2. *Dorocidaris namadica* Duncan, portion d'ambulacre grossie; *2a*, plaques coronales grossies.
3. *Salenia Keatingei* R. Fourtau, face supérieure *3a*, fare inférieure; *3b*, profil (gr. nat.); *3c*, apex grossi; *3d*, ambulance grossi; *3e*, interambulacre grossi.
4. *Cyphosoma namadicum* R. Fourtau, face supérieure; *4a*, face inférieure; *4b*, profil (gr. nat.); *4c*, interambulacre grossi; *4d*, ambulacre grossi.

PLANCHE 2.

1. *Echinobrissus Haydeni* R. Fourtau, face supérieure; *1a*, face inférieure; *1c*, face postérieure; *1d*, profil (gr. nat.).
2. *Hemiaster Oldhami* R. Fourtau, profil; *2a*, face postérieure; *2b*, face supérieure; *2c*, face inférieure (gr. nat.).
3. *Hamiaster Oldhami* R. Fourtau, face supérieure; *3a*, profil (grand. natur.); *3b*, rosette ambulacraire grossie.
4. *Opisaster* sp. ind., face supérieure; *4a*, profil (gr. nat.).
5. *Opisaster subsimilis* R. Fourtau, face supérieure; *5a*, profil (gr. nat); *5b*, face inférieure (gr. nat.); *5c*, ambulacre IV grossi; *5d*, ambulacre III grossi.

[1] Vredenburg.—The Ammonites of the Bagh Beds. *Records, G. S. I.*, XXXVI, part 3, pls. 14 et 15.

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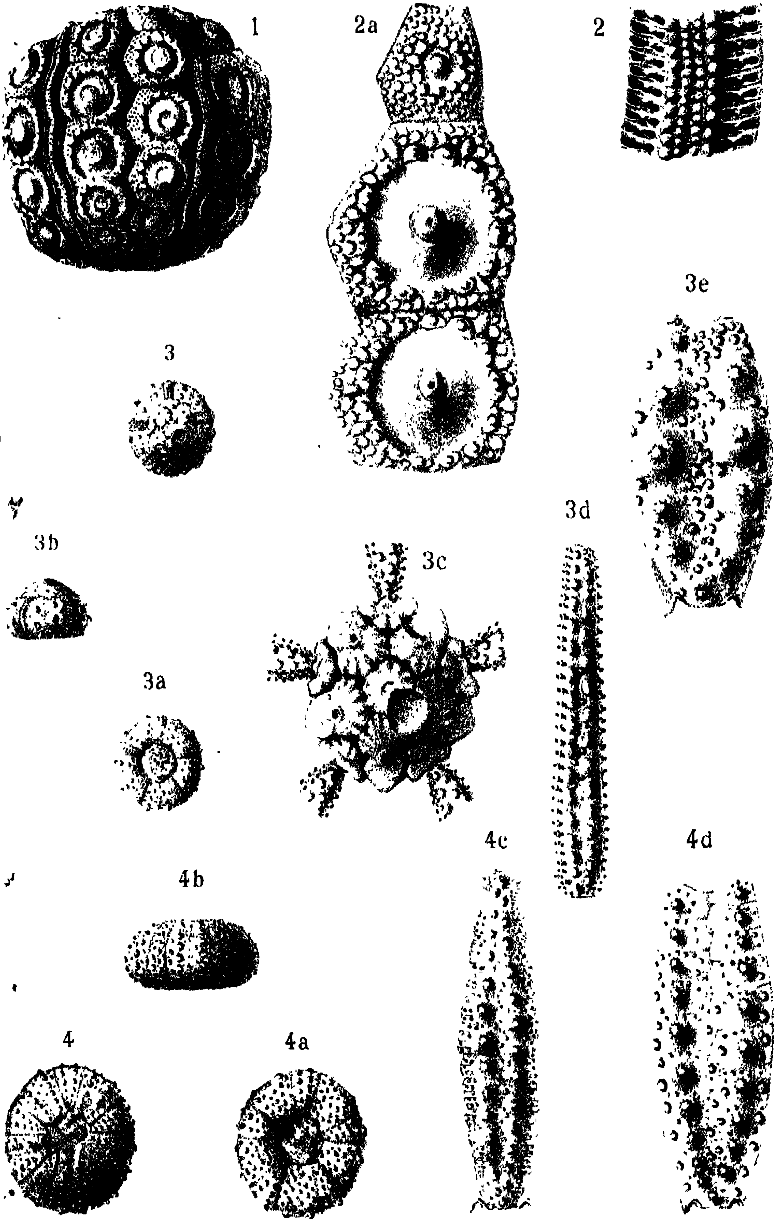

Sketch by F. Gauthier

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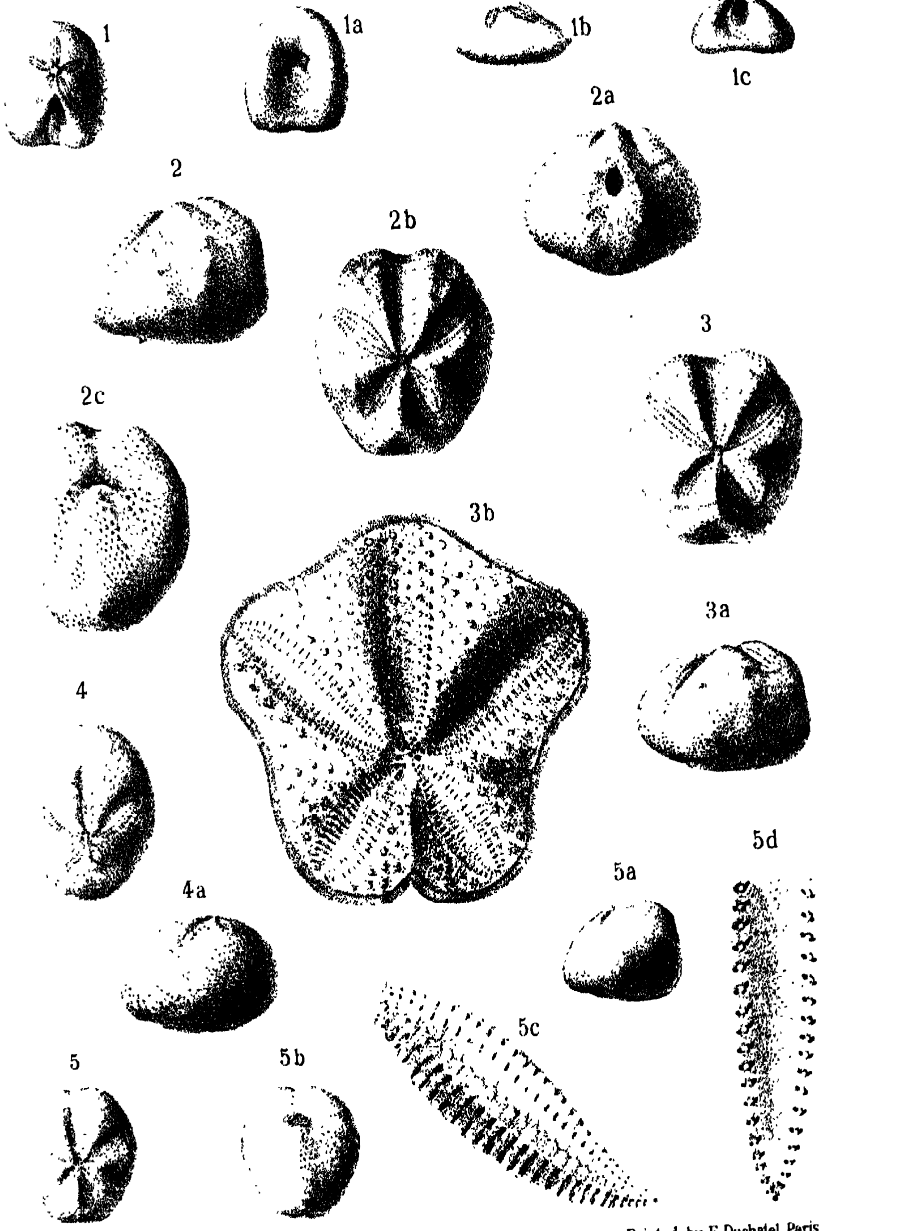
Echinides des "Bagh beds" (Pl. 1)

R. Fourtau.



Sketch by F. Gauthier.

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Echinides des "Bagh beds" (Pl. II)

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1918. [October.

THE MINERAL PRODUCTION OF INDIA DURING 1917. BY H. H. HAYDEN, C.I.E., F.R.S., *Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII), although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. The methods of collecting the returns are becoming more precise every year and the machinery employed for the purpose more efficient. Hence the number of minerals included in Class I—for which approximately trustworthy

annual returns are available—is gradually increasing, and it is hoped that before long the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will be reduced to a very small number. In the case of minerals still exploited chiefly under primitive native methods and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible, but the total error from year to year is not improbably approximately constant and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small indigenous alluvial industry contributes such an insignificant portion to the total outturn that any error from this source may be regarded as negligible.

From table I it will be seen that there has been an apparent increase of nearly £1½ million or 12½ per cent. in the value of the total production over that of 1916. The value figures, however, are largely artificial. In some instances although the output has fallen in quantity, it has increased in value; such increase does not necessarily give a true indication of the state of an industry, since the prevailing high freights and increased cost of production have in certain cases resulted in the closing down of all but high-grade propositions.

Mineral concessions granted.

The number of mineral concessions granted during the year amounted to 574 as against 532 in the preceding year; 515 of these were prospecting licenses and 39 mining leases. As in the preceding year, most of the increase is due to prospecting activity in Lower Burma

TABLE 1.—*Total value of Minerals for which returns of Production are available for the years 1916 and 1917.*

Mineral.	1916.	1917.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Coal	3,878,564	4,511,645	633,081	...	+16·3
Gold	2,303,023	2,221,889	...	81,134	—3·5
Manganese-ore . .	1,487,026	1,501,080	14,054	...	+·9
Petroleum . . .	1,119,405	1,092,964	...	26,441	—2·4
Salt	728,358	983,157	254,799	...	+34·9

TABLE 1.—*Total value of Minerals for which returns of Production are available for the years 1916 and 1917*—contd.

Mineral.	1916.	1917.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Tungsten-ore	497,397	623,074	125,677	...	+25·3
Saltpetre	607,488	527,666	...	79,822	—13·1
Lead and Lead-ore	428,383	510,539	82,156	...	+19·1
Mica(*a*)	311,680	508,173	196,493	...	+ 63
Building materials and road metal.	209,334	249,776	40,442	...	+19·3
Silver	88,687	237,216	148,529	...	+167·5
Tin-ore and tin	39,302	66,533	27,231	...	+69·3
Jadestone(*a*)	48,926	67,502	18,576	...	...
Monazite	37,714	56,489	18,775	...	+50
Ruby, sapphire and spinel.	37,513	51,831	14,318	...	+38·2
Iron-ore	37,981	39,977	1,996	...	+5·2
Copper-ore	3,259	30,162	26,903	...	+825·5
Chromite	16,401	26,216	9,815	...	+59·8
Magnesite	14,065	14,559	494	...	+3·5
Clay	4,645	9,019	4,374	...	+94·1
Steatite	2,628	6,470	3,842	...	+146·2
Corundum	2,783	3,874	1,091	...	+39·2
Alum	6,205	3,707	...	2,498	—40·3
Diamond	361	1,826	1,465	...	+405·8
Ochre	941	1,630	689	...	+73·2
Gypsum	745	1,034	289	...	+38·8
Amber	157	684	527	...	+335·7
Molybdenite	202	626	424	...	+209·9
Bauxite	463	620	157	...	+33·9
Graphite	1,501	547	...	954	—63·5
Asbestos	...	303	303	...	...
Agate	783	255	...	528	—67·5
Bismuth	...	163	163	...	...
Antimony-ore	503	139	...	364	—72·4
Platinum	46	19	...	27	—58·7
Total	**11,916,469**	**13,351,364**	1,626,663	191,768	+12·4
			+1,434,895		

(*a*) Export values.

II.—MINERALS OF GROUP I.

Chromite.	Gold.	Lead.	Monazite.	Salt.
Coal.	Graphite.	Magnesite.	Petroleum.	Saltpetre.
Copper.	Iron.	Manganese.	Platinum.	Silver.
Diamonds.	Jadeite.	Mica.	Ruby, Sapphire and Spinel.	Tin.
				Tungsten.

Chromite.

The remarkable rate of increase in the production of chromite recorded in the preceding year was not maintained in 1917. There was, however, an increase of over 34 per cent. in the output. This was due almost entirely to operations in Baluchistan, where the output was more than doubled. There was a slight increase in the Singhbhum production, and a decrease in Mysore.

TABLE 2.—*Quantity and Value of Chromite produced in India during 1916 and 1917.*

	1916.		1917.	
	Quantity	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Baluchistan	7,620	7,620	15,659	15,659
Bihar and Orissa . . .	2,737	2,495	3,266·4	3,111
Mysore	9,802	6,286	8,136	7,446
Total .	**20,159**	*16,401*	**27,061·4**	*26,216*

Coal.

There was an increase of nearly a million tons or 5½ per cent., and a proportionately greater increase in value —16·3 per cent.—in the output of coal. The pit's mouth value increased largely everywhere, except in the case of Hyderabad. There was an increase of Rs. 9 per ton in pit's mouth value in the North-West Frontier Province, but as the output is less than 100 tons, the figures for that province may be left out of consideration. In the fields of Bengal and Bihar and Orissa, the rates of increase were respectively Re. 0-6-4 and Re. 0-6-0 per ton.

TABLE 3.—*Average price (per ton) of Coal extracted from the Mines in each province during the year 1917.*

Province.	Average price per ton.		
	Rs.	A.	P.
Assam	7	0	7
Baluchistan	11	0	11
Bengal	3	15	1
Bihar and Orissa	3	5	10
Central India	3	6	2
Central Provinces	4	1	3
Hyderabad	6	0	0
North-West Frontier Province	14	0	0
Punjab	7	8	8
Rajputana	4	5	8

TABLE 4.—*Origin of Indian Coal raised during 1916 and 1917.*

—	Average of last five years.	1916.	1917.
Gondwana Coalfields	15,937,670	16,863,466	17,814,524
Tertiary Coalfields	409,700	390,843	398,394
Total	...	17,254,309	18,212,918

There was a fall of over 50 per cent. in the amount of coal exported, and a small rise in imports. The total amount of coal, coke and patent fuel imported, however, was only 37,626 tons. The quantity exported was 408,117 tons against nearly 882,000 tons in 1916.

There was a general increase in the output of coal in most provinces, with the exception of Baluchistan, Bengal, Central India and Rajputana. The decrease in Bengal amounted to nearly 361,000 tons; Bihar and Orissa, on the other hand, shows an increase of over a million tons, the Central Provinces nearly 84,000 tons, and Hyderabad over 65,000 tons. The decrease in the output of the Bikaner coalfield in Rajputana amounted to more than 50 per cent. as compared with the preceding year.

TABLE 5.—*Provincial Production of Coal during the years 1916 and 1917.*

Province.	1916.	1917.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Assam	287,315	301,480	14,165	...
Baluchistan	42,163	40,785	...	1,378
Bengal.	4,992,376	4,631,571	...	360,805
Bihar and Orissa . . .	10,767,683	11,932,419	1,164,736	...
Burma.	200,285	198,407	...	1,878
Central India . . .	287,832	371,498	83,666	...
Central Provinces . . .	615,290	680,629	65,339	...
Hyderabad	75	215	140	...
North-West Frontier Province	47,449	49,869	2,420	...
Punjab	13,841	6,045	...	7,796
Rajputana (Bikaner) . .	...	...	...	...
Total .	**17,254,309**	**18,212,918**	***1,330,466***	***371,857***

TABLE 6.—*Output of the Gondwana Coalfields for the years 1916 and 1917.*

Coalfields.	1916.		1917.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Bengal, Bihar and Orissa—				
Daltonganj . . .	76,298	·44	79,627	·44
Giridih	866,055	5·02	824,007	4·52
Jaintia	75,089	·44	86,894	·48
Jharia	8,950,318	51·87	9,783,788	53·72
Bokaro-Ramgarh . .	197,255	1·14	360,760	1·98
Raniganj	5,535,307	32·09	5,376,022	29·52
Sambalpur (Hingir-Rampur).	59,737	·35	52,892	·29
Central India—				
Umaria	200,285	1·16	198,407	1·09
Central Provinces—				
Ballarpur . . .	84,889	·49	95,303	·52
Pench Valley . . .	154,548	·9	204,502	1·12
Mohpani	48,395	·28	71,693	·39
Hyderabad—				
Singareni	615,290	3·56	680,629	3·74
Total .	**16,863,466**	**97·74**	**17,814,524**	**97·81**

TABLE 7.—*Output of Tertiary Coalfields for the years 1916 and 1917.*

Coalfields.	1916. Tons.	1916. Per cent. of Indian Total.	1917. Tons.	1917. Per cent. of Indian Total.
Assam—				
Makum . . .	283,830		291,484	
Naga Hills . . .	3,135	1·66	8,906	1·65
Sibsagar . . .	...		915	
Khasi and Jaintia Hills .	350		175	
Baluchistan—				
Khost	32,995	·19	29,517	·22
Sor Range . . .	9,168	·05	11,268	
North-West Frontier Province—	75		215	
Punjab—				
Jhelum	44,944	·28	40,322	·29
Mianwali . . .	817		2,916	
Shahpur . . .	1,688		6,631	
Rajputana—				
Bikaner . .	13,841	·08	6,045	·03
Total .	390,843	2·26	398,394	2·19

The average number of persons employed daily in the coalfields increased by nearly 11,000 or rather less than 7 per cent. The average output per person employed was 108·88 tons as against 110·21 in the preceding year. The total number of fatal accidents was 172 or 1·02 per thousand persons employed.

TABLE 8.—*Average number of persons employed daily in the Indian Coalfields during 1916 and 1917.*

Province.	Number of persons employed daily.		Output per person employed.	Number of deaths by accidents.	Death-rate per 1,000 persons employed
	1916.	1917.	1917.	1917.	1917.
Assam . . .	2,814	2,952	102·1	24	8·13
Baluchistan . .	1,111	955	42·7	8	8·37
Bengal . . .	43,040	38,585	120·03	35	·9
Bihar and Orissa .	92,053	106,571	111·96	83	·77
Central India . .	1,480	1,244	159·49	1	·8
Central Provinces .	3,558	4,245	87·51	11	2·59
Hyderabad . .	11,299	11,566	58·84	8	·69
North-West Frontier Province.	7	14	15·35	...	...
Punjab . . .	1,049	1,033	48·27	2	1·93
Rajputana (Bikaner) .	143	107	56·5	..	...
Total .	**156,554**	**167,272**	...	172	...
AVERAGE .			108·88		1·02

Copper.

There was a large increase in the output of copper ore in Singhbhum from 2,173 tons, valued at £3,259, in 1916 to 20,108 tons valued at £30,162 in the year under review. It is hoped that the smelting operations of the Cape Copper Co. will soon result in a considerable increase in output.

TABLE 9.—*Production of Copper-ore during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar and Orissa— Singhbhum . . .	2,173	3,259	20,108	30,162
Burma— Katha	498	1,347	...	...
Total .	***2,671***	***4,606***	***20,108***	***30,162***

Diamonds.

The output of diamonds was again insignificant, being only 18·2 carats. The value (£1,827), however, shows a marked increase over that of the output of the preceding year.

Gold.

There was a further decrease amounting to 24,000 oz. in the output of gold. As in the preceding year, this was due chiefly to fall in the Kolar production. There was also a fall of over 5,000 oz. in the Hyderabad fields and of nearly 2,000 oz. in Madras. The output in Singhbhum increased from 864 oz. to 2,462 oz.

TABLE 10.—*Quantity and value of Gold produced in India during 1916 and 1917.*

—	1916.		1917.		
	Quantity.	Value.	Quantity.	Value.	Labour
	ozs.	£	ozs.	£	
Bihar and Orissa—					
Singhbhum	864	3,977	2,462	10,133	119
Burma—					
Myitkyina	1,901·05	7,289	1,005·55	3,895	
Katha	21·21	85	31·19	113	165
Upper Chindwin	46·96	276	42·18	240	
Shwebo	7·41	36	...	...	...
Salween	6	24	...	...	...
Hyderabad	18,657·2	71,577	13,466·7	52,013	1,140
Madras	22,371	94,789	20,529	87,066	1,768
Mysore	554,301	2,124,129	536,559	2,067,541	24,531
Punjab	186·23	810	190·08	857	407
United Provinces	7·63	31	7·31	31	39
Total	**593,369·69**	***2,303,023***	**574,293·01**	***2,221,889***	28,169

Graphite.

There was a considerable reduction in the production of graphite in Kalahandi, where the output fell from 252 tons, valued at £168, in 1916 to 60·4 tons, valued at £242, in the year under review, while in Rajputana there was a still greater fall from 1,066·4 to 42·3 tons valued at £305.

Iron.

There was a small rise in the output of iron-ore. The Tata Iron and Steel Company produced 167,870 tons of pig iron and 114,027 tons of steel including steel rails, while the Bengal Iron and Steel Company produced 80,262 tons of pig and 2,256 tons of cast-iron castings. In the Central Provinces there was a slight increase in the number of indigenous furnaces at work, 312 being operated during the year; at the same time there was a fall in production.

TABLE 11.—*Quantity and value of Iron ore produced in India during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Tons	£	Tons.	£
Bihar and Orissa—				
Singhbhum	150,258	10,919	184,815	13,778
Orissa	240,918	21,271	195,998·5	17,543
Burma	16,081	4,288	28,763	7,670
Central Provinces	4,464·3	1,493	3,669	978
Rajputana	33·5	9	25	7
United Provinces	3	1	2·2	1
Total	411,757·8	*37,981*	413,272·7	*39,977*

Jadeite.

There was a slight increase in the output of jadeite produced in Burma from 3,783·37 cwt. in 1916 to 3,961·28 cwt. in the year under review. There was a very marked increase in the value from £9,315 to £28,931. This increase is attributed to a preponderance in the output of the high-grade qualities used for jewellery and other ornamental purposes.

Lead.

There was a very large increase in the output of ore from the Bawdwin mines, which rose from about 14,000 tons in 1916 to over 71,000 tons in the year under review. There was not, however, a commensurate increase in the amount of lead extracted, which was only 16,962 tons, as against 13,790 tons in the preceding year. There was an increase of over 100 per cent., however, in the quantity of silver extracted, which amounted to 1,580,557 oz. in 1917 as against 759,012 oz. in the preceding year.

TABLE 12.—*Production of Lead and Silver ore during 1916 and 1917.*

	1916.			1917.		
	QUANTITY.	VALUE.		QUANTITY.	VALUE.	
	Lead-ore and lead.	Lead-ore and slag.	Silver.	Lead-ore and slag.	Lead-ore and lead.	Silver.
	Tons.	£	£	Tons.	£	£
Burma—						
Northern Shan States	8,839 (ore)	273,850(*a*)	70,732	54,616 (ore)	451,555(*g*)	228,756
	4,771 (slag)	147,976(*b*)	15,989	6,282 (slag)	48,017(*h*)	4,361
	202 (gossan flux)	6,239(*c*)	1,831	10,589 (gossan flux)	9,292(*i*)	3,966
Southern Shan States.	143·58	275	...	146·8	1,675	...
Central Provinces.—						
Drug . .	7	43	..	...	...	...
Kashmir . .	7·2(*d*)	...	.	...	...	...
Mysore—						
Chitaldrug .	1·78	(*e*)	. .	·09	(*j*)	..
Total .	13,971·56	*428,383*	*88,552*(*f*)	71,633·89	*510,539*	*237,083*(*k*)

(*a*) Value of 8,822 tons of lead extracted.
(*b*) Value of 4,767 tons of lead extracted.
(*c*) Value of 201 tons of lead extracted.
(*d*) Dug-out by a licensee under a prospecting license. Value not returned.
(*e*) Value not returned.
(*f*) Value of 759,012 ozs. of silver extracted
(*g*) Value of 15,051·85 tons of lead extracted.
(*h*) Value of 1,600·56 tons of lead extracted.
(*i*) Value of 309·72 tons of lead extracted.
(*j*) Value not returned.
(*k*) Value of 1,580,557 ozs. of silver extracted

Magnesite.

There was a further slight increase in the production of magnesite, which rose from 17,640 tons in 1916, to 18,202 tons, valued at £14,559, in the year under review.

TABLE 13.—*Quantity and value of Magnesite produced in India during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value.	Quantity.	Value
	Tons.	£	Tons.	£
Madras—				
Salem	17,540	14,032	18,192	14,554
Mysore	100	33	10	5
Total	**17,640**	*14,065*	**18,202**	*14,559*

Manganese.

There was a slight fall in the production of manganese, but at the same time the value of the output was higher than that of the preceding year. This, of course, is due to the artificial conditions prevailing at present.

TABLE 14.—*Quantity and value of Manganese ore produced in India during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value *f. o. b.* at Indian ports.	Quantity.	Value *f. o. b.* at Indian ports.
Bihar and Orissa—	Tons.	£	Tons.	£
Singhbhum	2	4	126	292
Gangpur	2,832	6,018	11,780	27,290

TABLE 14.—*Quantity and value of Manganese ore produced in India during 1916 and 1917*—contd.

	1916.		1917.	
	Quantity.	Value f. o. b. at Indian ports.	Quantity.	Value f. o. b. at Indian ports.
	Tons.	£	Tons.	£
Bombay—				
Belgaum . . .	1,765	3,751		
Chota Udepur . .	7,951	16,896	417	966
Panch Mahals . .	46,160	98,090	26,690	61,832
Central Provinces—				
Balaghat . . .	264,032	627,076	260,706	686,526
Bhandara . . .	86,344	205,067	44,997	118,492
Chhindwara . . .	53,977	128,195	66,235	174,419
Nagpur . . .	153,899	365,510	145,603	383,421
Jubbulpore . . .	576	727	300	790
Madras—				
Vizagapatam . . .	2,755	2,893	1,682	1,864
Mysore	24,911	32,799	32,277	45,188
Total .	645,204	*1,487,026*	590,813	*1,401,080*

Mica.

As in the case of manganese, there was an apparent fall in the amount of mica produced, but a rise in the value of the output, the total production in 1917 being returned as 40,907·6 cwt. valued at £141,605. The amount exported, on the other hand, was 62,434 cwt., or over 50 per cent. more than the quantity reported as produced in the country. This cannot be due entirely to stocks held from previous years, and, as has been pointed out before, indicates imperfect returns. Owing to the recent heavy demand for mica and to the higher prices offered, there was increased activity in mining during the past year, and there is very little doubt that the output figures are too low. There is a thriving trade in mica theft in some of the mining areas, and stolen mica naturally does not appear in the output returns.

TABLE 15.—*Quantity and Value of Mica produced in India during 1916 and 1917.*

	1916.		1917.	
	Quantity	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
Bihar and Orissa . . .	26,819·8	76,940	34,137	91,825
Madras	15,675	28,945	6,050·4	45,718
Mysore	18	72		
Rajputana	887	3,287	720·2	4,062
Total .	43,399·8	*109,244*	40,907·6	*141,605*

Monazite.

The production of monazite in Travancore rose from 1,292·48 tons valued at £37,714 in 1916 to 1,940·3 tons valued at £56,489 in 1917.

Petroleum.

There was a decrease of over 14 million gallons in the output of petroleum in Burma and India, the total production being 282,759,523 gallons. The details of the respective fields are shown in the attached table. The production of the Yenangyaung Oilfield fell from nearly 199 million gallons in 1916 to 176,979,020 gallons in the year under review. The yield of the Singu Oilfield was 85,639,166 gallons, approximately the same as in the preceding year. There were slight increases in the outputs of the Yenangyat and Minbu fields, but a falling off in Kyaukpyu. In Assam the output of the Digboi Field increased by over 1 million gallons, or nearly 23 per cent, while the new Badarpur field in Assam produced nearly 3 million gallons. In the Punjab the Attock Oilfield increased its production more than threefold, the output having risen from a little over 182,000 gallons to 618,598 gallons in 1917.

TABLE 16.—*Quantity and Value of Petroleum produced in India during 1916 and 1917.*

	1916		1917.	
	Quantity.	Value.	Quantity.	Value.
	Gallons.	£	Gallons.	£
Burma—				
Akyab	11,882	228	10,894	210
Kyaukpyu	68,843	321	46,821	1,408
Yenangyaung Field	199,152,938	766,562	176,979,020	681,212
Singu Field	85,146,138	305,002	85,639,166	329,635
Yenangyat Field	5,310,740	19,980	6,620,908	24,825
Minbu	2,043,542	8,515	3,468,382	14,452
Thayetmyo	35,000	293	30,000	253
Assam—				
Digboi (Lakhimpur)	5,236,890	17,274	6,419,840	21,176
Badarpur			2,924,975	14,625
Punjab—				
Attock	182,480	1,216	618,598	5,155
Mianwali	1,334	14	919	13
Total	297,189,787	*1,119,405*	282,759,523	*1,092,964*

The imports of kerosene oil decreased largely in 1917, being only a little over 33 million gallons as compared with nearly 60 million gallons in the preceding year. 438,888 cwt. of paraffin wax, valued at £669,479, were exported.

Platinum.

The output of platinum fell to almost nothing, being only 3·79 oz; this was obtained, as usual, during the dredging operations of the Burma Gold Dredging Company at Myitkyina.

Ruby, Sapphire and Spinel.

There was a slight decrease in the output of the Ruby Mines during the year under review. The estimated value of the output however, rose to £51,831.

TABLE 17.—*Quantity and Value of Ruby, Sapphire and Spinel produced in India during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Carats.	£	Carats.	£
Burma—				
Mogok	136,783 (Rubies)	35,848	132,409 (Rubies)	43,575
	34,100 (Sapphires)	1,442	32,369 (Sapphires)	8,017
	38,841 (Spinel)	223	33,422 (Spinel)	239
Total	**209,724**	*37,513*	**198,200**	*51,831*

Salt.

There was a slight decrease in the amount, and a slight rise in the value, of the output of salt in 1917 as compared with that of the preceding year. There was also a slight decline in the amount imported, from 446,069 tons, valued at £1,260,295 in 1916, to 341,986 tons valued at £1,360,093 in the year under review.

TABLE 18.—*Quantity and Value of Salt produced in India during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Aden	129,406	45,614	122,926	65,952
Bengal	2	1	21	28
Bombay and Sind	484,742	128,420	457,989	
Burma	38,774	184,812	43,650	229,882
Central India	6·7	32	25·1	114
Gwalior State	114	364	269	854
Kashmir	36·7	27	...	...
Madras	481,170	267,065	394,985	384,617
Northern India	354,398·	102,023	405,731	136,917
Rajputana	...	...	2,057	247
Total	**1,488,649·4**	728,358	**1,427,653·1**	983,157

TABLE 19.—*Quantity and Value of Rock-Salt produced in India during 1916 and 1917.*

	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Salt Range	160,358	27,283	152,351	25,921
Kohat	19,978	1,983	23,787	2,509
Mandi	4,568	5,440	4,829	5,752
Total .	**184,904**	*34,706*	**180,967**	*34,182*

Saltpetre.

The production of saltpetre fell from over 25,000 tons in 1916 to 21,283·8 tons valued at £527,666 in 1917. Most of the reduction occurred in the United Provinces. There was an increase in the quantity exported, which amounted to 515,374 cwt., valued at £677,856, in 1917 as against 485,000 cwt. in the preceding year.

TABLE 20.—*Quantity and value of Saltpetre produced in India during 1916 and 1917.*

	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£.	Tons.	£.
Bihar	5,904	143,188	5,024·3	122,995
Central India	25·1	481	28·9	252
Punjab	8,140·	191,878	9,141	226,793
Rajputana	244	5,700	234·2	6,893
United Provinces . . .	10,743	266,241	6,855·4	170,733
Total .	**25,056·1**	*607,488*	**21,283·8**	*527 666*

Silver.

Practically the whole of the silver production comes from the Badwin lead-zinc mines, which, as already stated (see *Lead*), produced 1,580,557 oz. in the year under review. The Anantapur gold mine in Madras also produced 1,281 oz.

Tin.

There was a considerable increase—amounting to 43 per cent.—in the amount of tin-ore produced. This all came from Burma, which yielded 13,326 cwt. valued at £65,533. 2,817·9 cwt. of block tin were also produced in Mergui district as the result of local smelting operations. The imports of block tin amounted to 28,180 cwt., valued at £292,135.

N.B.—The tin-ore of the Southern Shan States is produced in the form of mixed cassiterite-wolfram concentrates; the output is therefore returned in terms of the mixed concentrate, the approximate composition of which is usually 43 per cent. wolfram to 57 per cent. cassiterite. The total figure for 1917 is 14,239 cwt.; for the purposes of this *Review* it has been assumed that 8,088 cwt. of this represent tin-ore and the remainder wolfram.

TABLE 21.—*Quantity and value of Tin and Tin-ore for the years 1916 and 1917.*

—	1916.				1917.			
	Block Tin.		Tin Ore.		Block Tin.		Tin Ore.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwt.	£.	Cwt.	£	Cwt.	£	Cwt.	£
Burma—								
Amherst .	...	...	10	16	...	...	33	176
Mergui . .	2,257·19	19,802	1,897	10,531	2,817·9	27,962	1,761	10,930
Southern Shan States.	...	...	4,862	16,965	...	...	8,088	40,440
Tavoy . .	...	...	1,644	8,192	...	...	1,762	11,015
Thaton . .	...	...	900	3,598	...	...	1,677	3,972
Total .	**2,257·19**	*19,802*	**9,313**	*39,302*	**2,817·9**	*27,962*	**13,321**	*66,533*

Tungsten.

The production of wolfram rose by nearly 22 per cent., from a little under 3,700 tons in 1916 to over 4,500 tons in the year under review. The Central Provinces have now ceased to produce, and there has only been a small increase in the output in Singhbhum. The output of the Degana mines in Rajputana has increased somewhat but is still insignificant, the absence of water being a serious handicap to efficient treatment of the material. Over 80 per cent. of the total output of wolfram came from Tavoy, where the industry has shown highly satisfactory progress, the production having increased by nearly 75 per cent. during the last two years.

TABLE 22.—*Quantity and value of Tungsten-ore produced in India during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum	8	640	20	1,333
Burma [1]—				
Mergui	340	46,014	368	49,541
Southern Shan States [2] .	185	18,500	307	39,910
Tavoy	3,034	410,586	3,697·5	508,794
Thaton	91·5	15,079	107·5	15,366
Central Provinces—				
Nagpur	1·3	220	...	...
Rajputana—				
Marwar	32·7	6,358	42	8,130
Total .	**3,692·5**	*497,397*	**4,542**	*623,074*

[1] Figures taken from "Note on the mineral production of Burma" for 1916 and 1917.
[2] See note under *Tin*.

III.—MINERALS OF GROUP II.

Agate.

The output of agates amounted to 120 tons valued at £255. All of these came from Rajpipla.

Alum.

The production of alum fell by nearly 50 per cent. from 9,419 cwt. in 1916 to 5,434 cwt. valued at £3,707 in 1917. This production was from the Mianwali district in the Punjab.

Amber.

59·6 cwt. of amber, valued at £684, were produced during the year in the Myitkyina district of Upper Burma.

Antimony.

The production of antimony ore fell from 1,040 tons in the year 1916 to 130·5 tons valued at £139 in the year under review. Of this 105 tons came from the Amherst district in Upper Burma and 25½ from the Chitaldrug district of Mysore.

Aquamarine.

Nearly 26,000 carats of aquamarine were produced from the Kashmir workings during the year under review. The output was valued at £297.

Asbestos.

A small quantity of asbestos was produced during the year, the total output being 148 tons valued at £303, of which 7 tons were produced in the Central Provinces and 141 tons in the Hassan district of Mysore.

Bauxite.

The output of bauxite in the Jubbulpore district amounted to 1,363 tons. The estimated value was £620. The output in the preceding year was 750 tons.

Bismuth.

A small quantity (5 cwt.) of bismuth was mined in the Tavoy district, where native bismuth is occasionally found associated with the wolfram. The estimated value of the output was £163.

Building Materials.

The total estimated value of building stone and road-metal produced during the year 1917 was £249,776.

Clay.

The production of clay was 86,745 tons valued at £9,019.

Corundum.

There was a slight increase in the output of corundum from 37,361 cwt. in 1916 to 41,425·8 cwt. in the year under review. With the exception of 200 cwt. from Rewah and 26 cwt. from South Canara, the whole of the production came from Assam.

TABLE 21.—*Production of Building Materials and road metal in India during the year 1917.*

—	GRANITE.		LATERITE.		LIME.		LIMESTONE AND KANKAR.		MARBLE.		SANDSTONE.		SLATE.		TRAP.		MISCELLANEOUS.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£
Assam .	..	..	..	..	..	..	57.100	5,178	..	..	..	..	..	..	..	..	..	..
Bihar and Orissa.	17,995	3.678	38,405	1,242	121	3	264.966	69,039	..	..	70,166	2,249	2,000	1,900	13,584	220	179,837	7,234
Bombay .	..	..	..	..	..	..	1,192	100	..	..	..	..	..	..	..	..	..	..
Burma .	255,290	18.730	286,924	13.091	..	..	174,034	12,437	..	..	86,636	6.195	..	..	677	34	295,954	19,723
Central India.	..	..	..	..	17,057	8,959	69,512	4,420	..	..	..	..	..	..	..	..	3,026	30
Central Provinces.	..	..	..	..	..	..	86,444	6,917	..	..	..	..	..	..	..	..	..	..
Hyderabad	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Madras .	58,878	2.466	97,042	3.905	..	..	9,541	551	..	..	..	..	..	..	..	..	83,518	5,900
North-West Frontier Province	..	..	..	..	..	..	2,541	114	..	..	..	..	..	..	..	..	..	..
Punjab .	..	..	..	..	..	..	15,497	895	..	..	109,432	7,269	6,831	7,798	..	..	9,208	143
Rajputana .	..	..	..	..	..	..	820	479	3,032	3,182	38,894	11,479	..	..	..	..	49,995	2,897
United Provinces.	..	..	..	..	63	28	3,361	805	..		5,000	1,500	43,025	546	..	..	136,452	18,440
TOTAL .	**332,163**	*24,874*	**422,371**	*18,238*	**17,241**	*8,990*	**685,008**	*100,935*	**3,032**	*3,182*	**310,128**	*28,692*	**51,856**	*10,244*	**14,261**	*254*	**757,990**	*54,367*

Gypsum. The output of gypsum shows a slight increase over that of the preceding year. The figures are given in table 22.

TABLE 23.—*Production of Gypsum during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Punjab—				
Jhelum	615	31	1,068	53
Rajputana—				
Bikaner (Jamsar) . .	11,613	520	8,116	661
Marwar . . .	3,800	194	7,499	320
Total .	**16,028**	*745*	**16,683**	*1,034*

Molybdenite. 27 cwt. of molybdenite, valued at £626, were produced from the Tavoy wolfram mines during the year 1917.

Ochre. The output of ochre rose from 850·5 tons in 1916 to 3,143 tons valued at £1,630 in the year under review.

TABLE 24.—*Production of Ochre during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar and Orissa	3·5	1	69	49
Central India . . .	839	939	2,174	773
Central Provinces	8	1	900	808
Total .	**850·5**	*941*	**3,143**	*1,639*

Samarskite. 67 lbs. of samarskite, valued at £2, were produced from the Sankara mica mine in Nellore.

Steatite. There was a very marked rise in the quantity of steatite produced. The total production amounted to 7,828·7 tons valued at £6,470.

TABLE 25.—*Quantity and value of Steatite produced in India during 1916 and 1917.*

—	1916.		1917.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum . . .	(a)	250	...	...
Mayurbhanj . . .	52	333	50	267
Burma —				
Meiktila . . .	...	...	4,846	1,197
Myingyan . . .	...	...	16	25
Central India—				
Bijwar	...	...	73·3	386
Central Provinces—				
Jubbulpore . . .	891·75	794	2,421·8	2,619
Madras—				
Bellary	36	12	23	8
Kurnool . . .	10·45	116	10·3	115
Nellore	50·5	251	19·5	77
Salem	87	325	149·6	762
Mysore	...	...	8·5	17
Rajputana (Ajmer-Marwara) .	...	...	119·7	319
United Provinces—				
Hamirpur . . .	76	504	80	630
Jhansi	10	43	11	48
Total .	**1,213·7**	*2,628*	**7,828·7**	*6,470*

(a) Quantity not returned.

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 26.—*Statement of Mineral Concessions granted during 1917.*

ASSAM.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cachar .	(1) Mr. F. H. Carslaw	Mineral oils .	P. L. .	16,000	21st May 1917.	1 year.
Khasi and Jaintia Hills.	(2) Khasi Hills prospecting and mining syndicate, Ltd.	Ore of tin, lead, titanium, silver, mercury, bismuth, nickel, cobalt, copper, zinc, antimony, arsenic, sulphur, tungsten, molybdenum, vanadium, uranium, tantalum, niobium, thorium, cerium, beryllium, zirconium, lanthanum, praseodymium, neodymium, samarium, yttrium, terbium, dysprosium, gadolinium, holmium, erbium, thulium, thallium, ytterbium, scandium, radium, iron and manganese, the minerals corundum and emery, the metal gold and minerals and metals carrying gold, the metal platinum and the platinum metals, and minerals and metals containing platinum and the platinum metals.	M. L. .	1,020	1st March 1917.	30 years.
Lakhimpur	(3) Assam Railways and Trading Co., Ltd.	Coal, iron, slate and shale.	M. L. .	2,227·2	1st April 1917.	Do.
Do. .	(4) Durga Datta and Srilal Beria.	Coal . . .	P. L. .	8,238·08	5th October 1917.	1 year.
Sylhet .	(5) The Burma Oil Co., Ltd.	Mineral oils .	P. L. .	11,603·2	15th May 1917.	Do.
Do.	(6) Do. .	Do. . .	P. L. .	2,944	Do. .	Do.

P. L.=*Prospecting License* M. L.=*Mining Lease.*

BALUCHISTAN.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kalat	(7) The Indo-Burma Petroleum Co., Ltd., Rangoon, through their Managing Agents, Messrs. Steel Brothers & Co.	Oil	P. L.	15,300	20th May 1917.	1 year.
Do.	(8) Do.	Do.	P. L.	17,920	Do.	Do.
Do.	(9) The Burma Oil Co., Ltd., Rangoon.	Do.	P. L.	24,900	18th December 1916.	Do.
Quetta-Pishin.	(10) Khan Bahadur B. D. Patel, C.I.E., Quetta.	Chromite	M. L.	80	1st July 1917.	30 years.
Do.	(11) Mr. Tikam Dass Girdhari Dass of Shikarpore.	Coal	M. L.	80	Do.	Do.
Sibi	(12) W. C. Clements, Esq., through his Agent Babu Ganda Singh.	Do.	M. L.	10·46	1st January 1917.	Do.
Do.	(13) Mr. Tikam Dass Girdhari Dass of Shikarpore.	Do.	M. L.	80	Do.	Do.

BIHAR AND ORISSA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Gya	(14) Mr. Surendra Nath Tagore of Calcutta.	Mica	M. L.	1,557·05	1st October 1915.	20 years.
Hazaribagh	(15) Babu Probodh Chandra Mukharji.	Do.	P. L.	80	20th August 1917.	1 year.
Do.	(16) Babu ShivajeeWaljee	Do.	P. L.	3·70	25th June 1917.	Do.
Do.	(17) Babu Jagannath Rasan Lal.	Do.	P. L.	280	18th September 1917.	Do.
Do.	(18) Babu Lakshmi Narain Sukhani.	Do.	P. L.	137·07	23rd August 1917.	Do.
Do.	(19) Babu Shivaji Walji	Do.	P. L.	3·23	10th October 1917.	Do.
Do.	(20) Babu Banka Behari Chaudhuri.	Do.	M. L.	70	Lease not yet executed.	30 years.
Sambalpur	(21) Mr. T. P. Yeoman	Coal	M. L.	1,300	1st July 1917.	Do.
Santal Parganas.	(22) Babu Bansi Ram Marwari.	Do.	M. L.	·33	1st October 1917.	6 months up to 31st March 1918.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BIHAR AND ORISSA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Santal Parganas.	(23) Babu Bansi Ram Marwari.	Coal . . .	M. L. .	1·90	1st October 1917.	6 months up to 31st March 1918.
Do .	(24) Babu Jamuna Prasad.	Do. . .	M. L. .	2·60	Do. .	Do.
Do.	(25) Babu Benode Behari Dey.	Do. . . .	M. L. .	2·15	Do. .	Do.
Do. .	(26) Messrs. Jardine Skinner & Co.	Do. . .	P. L. .	5,158·48	License not yet executed.	
Do. .	(27) E. Villiers, Esq.	Do. . . .	P. L. .	5,081·28	Do. .	
Do.	(28) Baidya Nath Dey	Do . .	M. L. .	10·15	17th December 1917.	Up to 31st March, 1918.
Singhbhum	(29) Singhbhum Chromite Co., Ltd., Calcutta.	Chromite . .	P. L. .	521·9	25th January 1917.	1 year.
Do. .	(30) Do.	Do. . .	P. L. .	633 6	Do. .	Do.
Do. .	(31) Babu Ajit Kumar Mallik, Howrah.	Yellow ochre .	P. L. .	11·90	8th January 1917.	Do.
Do. .	(32) Mr. S. Luxman Rao Naidu, Nagpur.	Chromite . .	M. L. .	216	25th April 1917.	15 years.
Do. .	(33) Do. .	Do. . .	M. L. .	596·30	Do. .	Do.
Do. .	(34) F. Dundas Whiffin, Esq., Panposh.	Manganese and iron ore.	P. L. .	12,800	14th October 1917.	1 year.
Do. .	(35) Mr. A. C. Maitra of Calcutta.	Chromite . .	P. L .	200	22nd May 1917.	Do.
Do. .	(36) The Bengal Iron and Steel Co., Ltd.	Manganese and iron ore.	P. L. .	1,088	Do.	Do.
Do. .	(37) Mr. A. C. Maitra of Calcutta.	Galena, gold and other kindred minerals.	P. L. .	1,330	22nd August 1917.	Do.
Do. .	(38) Babu Moti Lal Iswar Das of Calcutta.	Manganese . .	P. L. .	75·90	16th May 1917.	Do.
Do. .	(39) Babu Ajit Kumar Mallik of Howrah.	Red ochre . .	P. L. .	150	18th April 1917.	Do.
Do. .	(40) The Bengal Iron and Steel Co., Ltd.	Iron ore . .	P. L. .	56	16th June 1917.	Do.
Do. .	(41) Do. .	Do . .	M. L. .	800	7th December 1917.	30 years.
Do. .	(42) Mr. A. C. Moitra .	Chromite . .	P. L. .	360	24th July 1917.	1 year.
Do.	(43) The Bengal Iron and Steel Co., Ltd.	Manganese and iron ore.	M. L. .	1,267·2	Lease not yet executed.	30 years.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BIHAR AND ORISSA—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Singhbhum	(44) The Tata Iron and Steel Co.	Manganese and iron ore.	P. L.	22,144	The area consisted of two plots of lands, one measuring 9,792 acres and the other 12,352 acres. The license for the former land has been executed and the date of the commencement is 30th November, 1917. The license of the latter area has not yet been executed.	1 year.
Do.	(45) Messrs. M. D'Costa and Goredutt Ganesh Lal.	Chromite	P. L.	310	30th November 1917.	Do.
Do.	(46) Babu Mangi Lal Marwari.	Yellow and red ochre.	P. L.	4·60	16th October 1917.	Do.
o.	(47) Mr. A. C. Maitra	Gold	M. L.	1	Draft lease not yet executed.	20 years.
Do.	(48) Singhbhum Chromite Co., Ltd.	Chromite	M. L.	400 320	Lease not yet executed.	30 years.

BOMBAY.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Dharwar (also in Kanara district).	(49) Mr. L. C. Oliver	Galena	P. L.	1,143	18th June 1917.	1 year.
Kaira	(50) Shivrajpur Syndicate, Limited, by their agent H. J. Winch, Esq., Mine Manager, Shivrajpur.	Manganese and Aluminium.	P. L.	201·95	2nd July 1917.	Do.
Panch Mahals.	(51) Messrs. Shaw Wallace & Co., Managing Agents to the Bamankuva Mines.	Manganese ore	M. L.	680·22	1st June 1912.	8 years 1 month and 9 days.
Do.	(52) H. J. Winch, Mine Manager, Shivrajpur Syndicate, Shivrajpur.	Manganese	P. L. (renewal).	45·5	5th October 1917.	1 year.

P. L.= *Prospecting License.* M. L.= *Mining Lease.*

BOMBAY—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Sukkur .	(53) The Managing Agents, Indo-Burma Petroleum Co., Ltd., Rangoon.	Mineral oil . .	P. L. .	6,008	20th August 1917.	1 year.

BURMA.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Akyab .	(54) Messrs. The Burmah Oil Co., Ltd.	Mineral oil . .	P. L. .	3,620	1st September 1916.	1 year.
.	(55) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. (renewal).	5,440	15th December 1917.	2 years.
Amherst .	(56) Mukunda Lall Kundu.	All minerals (except oil).	P. L. .	640	23rd November 1916.	1 year.
Do. .	(57) Messrs. J. W. Darwood & Co.	Do. .	P. L. .	1,280	15th February 1917.	Do.
Do. .	(58) Messrs. T. D. Findlay & Son.	Do. .	P. L. .	426·66	10th February 1917.	Do.
Do. .	(59) Saw Bein Nga .	Do. .	P. L. .	640	13th February 1917.	Do.
Do. .	(60) Abdul Bari Chowdhry.	Do. .	P. L. .	640	5th February 1917.	Do.
Do. .	(61) Maung Ba Thein .	Do. .	P. L. .	640	10th March 1917.	Do.
Do. .	(62) Messrs. T. D. Findlay & Son.	Do. .	P. L. .	1,920	Do.	Do.
Do. .	(63) Maung Tun Hla .	Do. .	P. L. .	426·66	13th February 1917.	Do.
Do. .	(64) Maung Ba Tsee .	Do. .	P. L. .	640	20th April 1917.	Do.
Do. .	(65) Mr. L. Hong Seng .	Do. .	P. L. .	960	17th April 1917.	Do.
Do. .	(66) Mr. L. Gwan Shein	Do. .	P. L. .	1,280	20th April 1917.	Do.
Do. .	(67) Messrs. T. D'Castro & Son.	Do. .	P. L. .	640	17th April 1917.	Do.
Bhamo .	(68) Messrs. S. Crawshaw and B. Hardinge.	All minerals (except oil and jade).	P. L. .	5,516 8	11th December 1917.	Do.
Katha .	(69) Messrs. Jamal Bros. & Co., Ltd.	Tin, wolfram, silver, copper, lead, zinc and gold.	P. L. (renewal).	24,320	4th November 1916.	Do.
Lower Chindwin.	(70) Mr. A. K. A. S. Jamal.	All minerals (except oil).	P. L. (renewal).	1,680	23rd March 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Lower Chindwin.	(71) Messrs. Jamal Bros. & Co., Ld.	All minerals (except oil).	P. L. (renewal).	140	23rd March 1917.	1 year.
Do.	(72) Do.	Do.	P. L. (renewal).	1,120	Do.	Do.
Do.	(73) Messrs. The Burma Oil Co., Ltd.	Mineral oil	P. L.	640	15th August 1917.	Do.
Do.	(74) Do.	Do.	P. L. (renewal).	960	1st May 1917.	Do.
Do.	(75) Messrs. Jamal Bros. & Co., Ltd.	Do.	P. L. (renewal).	1,440	1st August 1917.	2 years.
Mergu	(76) U Shan Byu	All minerals (except oil).	P. L.	91·90	1st October 1916.	1 year.
Do.	(77) Tan Kar Lin and two others.	Tin	P. L.	29·16	15th January 1917.	Do.
Do.	(78) Maung San Mo	All minerals (except oil).	P. L.	583·68	26th January 1917.	Do.
Do.	(79) Maung Nyun	Do.	P. L.	2,876·48	10th March 1917.	Do.
Do.	(80) Messrs. Wightman & Co.	Tin	P. L.	53·76	26th February 1917.	Do.
Do.	(81) Maung Po Thaik	Wolfram and Tin	P. L.	486·40	12th February 1917.	Do.
Do.	(82) Mr. H. W. Watts	All minerals (except oil)	P. L.	2,343·60	22nd March 1917.	Do.
Do.	(83) Maung Pan On	Do.	P. L.	135·60	19th March 1917.	Do.
Do.	(84) Maung Po	Do.	P. L.	691·20	3rd April 1917.	Do.
Do.	(85) M. Haniff	Do.	P. L.	350·72	24th March 1917.	Do.
Do.	(86) Mrs. B. I. Jewett	Do.	P. L. (renewal).	3,056·64	12th February 1916.	Do.
Do.	(87) Do.	Do.	P. L. (renewal).	471·04	Do.	Do.
Do.	(88) M. Haniff	Do.	P. L. (renewal).	2,580·48	6th January 1917.	Do.
Do.	(89) Yew Shwe Ni	Do.	P. L. (renewal).	1,440	28th January 1917.	Do.
Do.	(90) C. Soo Don	Do.	P. L. (renewal.)	1,176·64	28th February 1917.	Do.
Do.	(91) U. Shwe Don	Do.	P. L. (renewal).	793·60	1st February 1917.	3 months.
Do.	(92) U. Shwe Thi	Do.	P. L. (renewal).	852·48	14th February 1917.	6 months.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(93) Nyaung Tat . .	All minerals (except oil).	P. L. (renewal).	353	18th March 1917.	1 year.
Do. .	(94) Messrs. Bulloch Bros. & Co., Ltd.	Do. .	P. L.	1,530 88	1st January 1917.	Do.
Do. .	(95) Yew Shwe Ni .	Do. .	P. L. .	1,775 52	20th April 1917.	Do.
Do .	(96) Mr. C. Swee Htin .	Wolfram . .	P. L. .	2,626 56	2nd May 1917.	Do.
Do. .	(97) Maung Ngwe Thi .	Wolfram and tin	P. L. .	746 52	3rd April 1917.	Do.
Do. .	(98) Mr. Meera Saib .	All minerals (except oil).	P. L. (renewal).	327·68	19th January 1917.	Do.
Do. .	(99) Maung Shwe Don .	Do. .	P. L. (renewal).	793·60	1st May 1917	3 months.
Do. .	(100) Tan Po Chit .	Do. .	P. L. .	320	18th September 1917.	1 year.
Do. .	(101) Ma Mo Thu .	Do. .	P. L. .	320	Do. .	Do.
Do. .	(102) Messrs. Finlay Fleming & Co.	Do. .	P. L. .	983 04	17th September 1917.	Do.
Do. .	(103) Mr. A. H. Noyes .	Do. .	P. L. (renewal).	100	26th November 1916.	Do.
Do. .	(104) U. Shwe Thi .	Do. .	P. L. (renewal).	852·48	15th August 1917.	6 months.
Do. .	(105) Mr. J. C. Galsbaun	Do. .	P. L. .	1,971 20	8th December 1917.	1 year.
Do. .	(106) Maung Maung .	Do. .	P. L. .	640	1st November 1917.	Do.
Do. .	(107) Mr. G. H. Hand .	Wolfram and tin	P. L. .	2,150 40	Do. .	Do.
Minbu .	(108) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil .	P. L. (renewal).	320 northern half of block 16 N of the Minbu Oil Field.	6th August 1916.	Do.
Do. .	(109) Maung Taik Gyi and Maung Shwe Mo.	Do. .	M. L. .	19 in Block 20 P of the Minbu Oil Field.	23rd February 1916.	30 years.
Do. .	(110) Messrs. The Yomah Oil Co., Ltd.	Do. .	P. L. .	2,570 24 Blocks 4 P, 8 P, 12 P, 24 P and portion of 11 P of the Minbu Oil Field.	23rd October 1917.	1 year.
Myingyan .	(111) Maung Tun Hman and three others.	Do. .	P. L. .	270	18th January 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mylagyan .	(112) Baljnath Singh .	Mineral oil .	P. L. .	11,520	27th August 1917.	1 year.
Myitkyina .	(113) Mr. H. F. Leslie .	Gold and platinum	P. L. .	1,132·8	4th January 1917.	Do.
Do. .	(114) Messrs. The Burma Gold Dredging Co. (1911), Ltd.	Gold and Iridio-Platinum.	P. L. (renewal).	3,200	23rd February 1917.	Do.
Do. .	(115) Mr. H. F. Leslie .	Gold . . .	P. L. (renewal).	2,931 2	1st April 1917	Do.
Do. .	(11) Do. .	Do. . .	P. L. (renewal).	640	1st November 1917.	Do.
Northern Shan States.	(117) Messrs. The Burma Mines, Ltd	Iron . . .	P. L. .	640	12th February 1917.	Do.
Do. .	(118) Do. .	Do. .	P. L .	2,560	14th March 1917.	Do.
Do. .	(119) Do. .	Coal . . .	P L .	3,200	17th March 1917.	Do.
Do. .	(120) Do. .	Do. . .	P. L. .	2,560	14th March 1917.	Do.
Do. .	(121) Messrs. The Mohochaung Exploration Co., Ltd.	Gold, silver, iron and zinc.	P. L. (renewal).	3,200	8th April 1917	Do.
Pakokku .	(122) Messrs. The British Burma Petroleum Co., Ltd.	Mineral oil .	P. L. .	261 & 614 40	19th December 1916.	Do.
Do. .	(123) Do. .	Do. .	P. L. (renewal).	76 80 & 371 20	14th November 1916.	Do.
Do. .	(124) Messrs The Nath Singh Oil Co., Ltd.	Do. .	P. L. (renewal).	1,020	12th January 1917.	Do.
Do. .	(125) Messrs The Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. .	800 East of Blocks Nos. 18, 19 and 20 in the Yenangyat Oil Field.	6th September 1917.	Do.
Do. .	(126) Messrs. The Nath Singh Oil Co., Ltd.	Do. .	P. L. (renewal).	12,399·4	26th April 1917.	2 years.
Do. .	(127) Messrs. The British Burma Petroleum Co., Ltd.	Do. .	P L. (renewal).	640	16th August 1917.	Do
Do. .	(128) Messrs. The Rangoon Oil Co., Ltd.	Do. .	P. L. (renewal).	320	Do.	Do.
Prome	(129) Maung Gyi . .	Do .	P. L. .	249·6	25th January 1917.	1 year.

P. L = *Prospecting License* M L = *Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Prome .	(130) Messrs. The Burmah Oil Co., Ltd.	Mineral oil .	P. L. (renewal).	3,200	7th June 1917	1 year.
Ruby Mines	(131) Ma Shwe Bwin .	Copper . .	P. L. .	640	25th April 1917.	Do.
Salween .	(132) Messrs. Steel Bros. & Co., Ltd.	All minerals (except oil).	P. L. .	3,840	5th December 1917.	Do.
Shwebo .	(133) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. .	1,280	9th January 1917.	Do.
Do. .	(134) Do. . .	Do. .	P. L. .	3,424	23rd February 1917.	Do.
Southern Shan States.	(135) Maung Law Pan .	Lead, copper and silver.	M. L.	2,080	1st July 1916	10 years.
Do. .	(136) Maung Ye . .	Wolfram . .	P. L. .	140	7th January 1917.	1 year.
Do. .	(137) Messrs. Bachardass Manekchand Kharwar.	Lead . . .	P. L. .	2,560	10th February 1917.	Do.
Do. .	(138) Maung Hnya .	Wolfram . .	P. L. .	228·73	5th April 1917.	Do.
Do .	(139) The Hon'ble Mr. Lim Chin Tsong.	All minerals (except oil).	P. L. (renewal).	166	20th November 1916.	Do.
Do. .	(140) Messrs. Steel Bros. & Co., Ltd.	Do. .	P. L. .	3,680	17th September 1917.	Do.
Do. .	(141) Do. . .	Do. .	P. L. .	2,560	4th September 1917.	Do.
Do. .	(142) Ko Law Pan .	Wolfram . .	P. L. .	64	17th August 1917.	Do.
Do. .	(143) Maung San Hein	All minerals (except oil).	P. L. .	160	4th September 1917.	Do.
Do. .	(144) Messrs. Bechardass Maneckchand Kharwar.	Wolfram . .	P. L. .	2,355·20	13th September 1917.	Do.
Do. .	(145) Maung Kya Ywet, A.T.M.	All minerals (except oil).	P. L. .	640	12th September 1917.	Do.
Do.	(146) Saw Lein Lee .	Do. .	P. L. (renewal).	599	30th May 1917.	Do.
Do. .	(147) Rathana . .	Gold . . .	P. L. .	3,200	27th December 1917.	Do.
Do. .	(148) Do. . .	Do. . .	P. L. .	1,440	Do. .	Do.
Do. .	(149) Do. . .	Do. . . .	P. L. .	4,920	Do.	Do.
Do. .	(150) Maung Par Aung .	All minerals (except oil).	P. L. .	640	28th December 1917.	Do.
Do. .	(151) Shain Thwe .	Do. . .	P. L. .	960	27th November 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Southern Shan States.	(152) Maung Po Ku .	All minerals (except oil).	P. L. .	2,560	21st November 1917.	1 year.
Tavoy .	(153) Messrs. The Hpaungdaw Prospecting Co., Ltd.	Do. .	P. L. .	2,688	3rd January 1917.	6 months.
Do. .	(154) Mr. H. G. Mathews	Do .	P. L. .	829	14th February 1917.	Do
Do. .	(155) Messrs. Hitakari & Co.	Do. .	P. L. .	512	27th January 1917.	Do.
Do. .	(156) Mr. A. E. Wallenberg.	Do. .	P. L. .	1,600	13th March 1917.	Do.
Do. .	(157) A. S. Mahomed .	Do. .	P. L. .	358	5th February 1917.	Do.
Do.	(158) Mr. James J. Milne	Do. .	P. L. .	813	2nd January 1917.	3 months.
Do. .	(159) Mr. A. G. Fraser	Do. .	P. L. .	922	22nd January 1917.	6 months.
Do. .	(160) Messrs. Lim Kim Seng Bros. & Co.	Do. .	P. L. .	922	4th January 1917.	Do.
Do. .	(161) Eu Shwe Swai .	Do. .	P. L. .	578	22nd March 1917.	Do.
Do. .	(162) Maung Sein Kaing	Do. .	P. L. .	640	8th January 1917.	Do.
Do. .	(163) Maung Ba Don .	Do. .	P. L. .	640	18th January 1917.	Do.
Do. .	(164) Eu Shwe Swai .	Do. .	P. L. .	640	15th March 1917.	Do.
Do. .	(165) Maung Ba Maung	Do. .	P. L. .	1,306	25th January 1917.	Do.
Do. .	(166) Maung Saw Hlaing	Do. .	P. L. .	548	2nd January 1917.	Do.
Do. .	(167) Netram Rambux	Do. .	P. L. .	240	4th January 1917.	Do.
Do. .	(168) Maung Saw Hlaing	Do. .	P. L. .	1,144	2nd January 1917.	Do.
Do. .	(169) Maung Po Swe .	Do. .	P. L. .	981	22nd January 1917.	Do.
Do. .	(170) Maung E Zin .	Do. .	P. L. .	435	15th February 1917.	Do.
Do. .	(171) Do. . .	Do. .	P. L. .	640	Do. .	Do.
Do. .	(172) Messrs. The High Speed Steel Alloys, Ltd.	Do. .	P. L. .	256	24th March 1917.	Do.
Do. .	(173) Maung Ba Maung	Do. .	P. L. .	1,920	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(174) Lim Eng Cheong	All minerals (except oil).	P. L.	671	22nd February 1917.	6 months.
Do.	(175) Maung Sein Thwe	Do.	P. L.	589	19th February 1917.	Do.
Do.	(176) Maung Khine	Do.	P. L.	800	24th February 1917.	Do.
Do.	(177) Maung Ni	Do.	P. L.	640	17th March 1917.	Do.
Do.	(178) Mr. R. C. N. Twite	Do.	P. L.	460	22nd March 1917.	Do.
Do.	(179) Mr. A. D. Brown	Do.	P. L.	189	8th March 1917.	Do.
Do.	(180) Ma Thaw	Do.	P. L.	563	5th March 1917.	Do.
Do.	(181) Mr. S. Crawshaw	Do.	P. L.	640	27th March 1917.	Do.
Do.	(182) Ma Mo Thu	Do.	P. L.	973	12th March 1917.	Do.
Do.	(183) Maung Gun	Do.	P. L.	768	3rd March 1917.	Do.
Do.	(184) Maung Shwe Gaing	Do.	P. L.	512	23rd March 1917.	Do.
Do.	(185) Ma Mya Yin	Do.	P. L.	1,075	26th March 1917.	Do.
Do.	(186) Maung Po Hnan	Do.	P. L.	640	Do.	Do.
Do.	(187) Mr. S. Merican	Do.	P. L.	512	22nd March 1917.	Do.
Do.	(188) Messrs. Steel Bros. & Co., Ltd.	Do.	P. L. (renewal).	640	16th November 1916.	Do.
Do.	(189) Ma Chein	Do.	P. L. (renewal).	808	8th November 1916.	Do.
Do.	(190) Maung Ni To	Do.	P. L. (renewal).	1,375	22nd December 1916.	Do.
Do.	(191) Maung Kyaw	Do.	P. L. (renewal).	435	19th November 1916	Do.
Do.	(192) Mahomed Aslam Khan.	Do.	P. L. (renewal).	1,536	16th December 1916.	Do.
Do.	(193) Khoo Zun Ni	Do.	P. L. (renewal).	1,280	7th December 1916.	Do.
Do.	(194) The Hon'ble Mr. Lim Chin Tsong.	Do.	P. L. (renewal).	770	Do.	Do.
Do.	(195) Do.	Do.	P. L. (renewal).	222	Do.	Do.
Do.	(196) Ong Hoe Kyin	Do.	P. L. (renewal).	179	13th December 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(197) Mr. A. S. Mahomed	All minerals (except oil).	P. L. (renewal).	1,804	12th December 1916.	6 months.
Do.	(198) San Sine Tin	Do.	P. L. (renewal).	107	16th December 1916.	Do.
Do.	(199) Mr. S. S. Halkar	Do.	P. L. (renewal).	1,587	1st January 1917.	Do.
Do.	(200) Messrs. Tata Sons & Co.	Do.	P. L. (renewal).	1,656	5th January 1917.	Do.
Do.	(201) Do.	Do.	P. L. (renewal).	780	9th December 1916.	Do.
Do.	(202) Mr. A. E. Wallenberg.	Do.	P. L. (renewal).	720	20th November 1916.	Do.
Do.	(203) Messrs. Steel Bros. & Co., Ltd.	Do.	P. L. (renewal).	1,818	28th December 1916.	3 months.
Do.	(204) M. A. Sooratee	Do.	P. L. (renewal).	609	17th January 1917.	1 year.
Do.	(205) Do.	Do.	P. L. (renewal).	640	1st February 1917.	Do.
Do.	(206) Maung Mya Pe	Do.	P. L. (renewal).	587	26th December 1916.	6 months.
Do.	(207) Ong Hoe Kyin	Do.	P. L. (renewal).	605	4th January 1917.	3 months.
Do.	(208) Quah Cheng Gwan	Do.	P. L. (renewal).	640	9th January 1917.	1 year.
Do.	(209) Messrs. Balthazar and Sons.	Do.	P. L. (renewal).	896	22nd December 1916.	6 months.
Do.	(210) Chan Kin Way	Do.	P. L. (renewal).	256	8th January 1917.	Do.
Do.	(211) San Sine Tin	Do.	P. L. (renewal).	911	9th February 1917.	Do.
Do.	(212) Chan Kin Way	Do.	P. L. (renewal).	371	26th January 1917.	1 year.
Do.	(213) Kho Zun Nee	Do.	P. L. (renewal).	614	28th January 1917.	Do.
Do.	(214) Messrs. The Tavoy Concessions, Ltd.	Do.	P. L. (renewal).	500	18th January 1917.	6 months.
Do.	(215) Maung Min Gyaw	Do.	P. L. (renewal).	1,182	8th February 1917.	Do.
Do.	(216) Maung Po Htin	Do.	P. L. (renewal).	988	9th March 1917.	Do.
Do.	(217) Ung Kyi Pe	Do.	P. L. (renewal).	279	15th September 1916.	Do.
Do.	(218) Mr. G. N. Marks	Do.	P. L. (renewal).	476	26th February 1917.	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(219) Mr. A. Rowland H. Ady.	All minerals (except oil).	P. L. .	1,280	28th June 1917.	1 year.
Do. .	(220) Maung Me . .	Do. .	P. L. .	614	5th June 1917	6 months.
Do. .	(221) Maung Paw Tun .	Do. .	P. L. .	947	19th April 1917.	Do.
Do. .	(222) Messrs. The Bombay Burma Trading Corpn., Ltd.	Do. .	P. L. .	708	10th April 1917.	Do.
Do. .	(223) Messrs. Foucar & Co., Ltd.	Do. .	P. L. .	112	17th May 1917.	Do.
Do. .	(224) Maung Ba Thaung Bros. & Co.	Do. .	P. L. .	1,280	22nd May 1917.	Do.
Do.	(225) Maung Paw Tun .	Do. .	P. L. .	343	14th June 1917.	Do.
Do.	(226) Messrs. Finlay, Fleming & Co.	Do. .	P. L. .	276	19th May 1917.	Do.
Do. .	(227) Maung Kya Pe, Maung Lu Chaw and Ma Kin.	Do. .	P. L. .	282	22nd June 1917.	1 year.
Do .	(228) Maung Saw Hlaing	Do. .	P. L. .	179	17th May 1917.	Do.
Do. .	(229) Mr. H. G. Mathews	Do.	P. L. .	71	13th June 1917.	Do.
Do. .	(230) Mr. A. Rowland Ady.	Do. .	P. L. .	184	11th June 1917.	Do.
Do. .	(231) Ma Hnit . .	Do. .	P. L. .	691	14th June 1917.	Do.
Do. .	(232) Mr. Ung Kyi Po .	Do. .	P. L. .	205	18th June 1917.	Do.
Do. .	(233) Maung Ze Ya	Do. .	P. L. .	484	31st May 1917.	Do.
Do.	(234) Maung Shwe Yin .	Do. .	P. L. .	240	19th June 1917.	Do.
Do. .	(235) Ma Kin .	Do.	P. L. .	800	Do.	6 months.
Do. .	(236) Mr. S. Crawshaw .	Do.	P. L. .	527	1st June 1917.	1 year.
Do. .	(237) Maung Tun Mya .	Do. .	P. L. .	282	15th June 1917.	Do.
Do	(238) Mr. Rowland H. Ady.	Do. .	P. L. .	588	28th June 1917.	Do.
Do.	(239) Messrs. The High Speed Steel Alloys Ltd.	Do. .	P. L. .	51	27th June 1917.	Do.
Do.	(240) Messrs. Finlay Fleming & Co.	Do. .	P. L. .	1,434	22nd June 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(241) Mr. Khoo Tun Byan.	All minerals (except oil).	P. L.	148	18th June 1917.	1 year.
Do.	(242) Maung Than and Ma Thein.	Do.	P. L.	580	29th June 1917.	Do.
Do.	(243) Mr. A. E. Wallenborg.	Do.	P. L.	320	28th June 1917.	Do.
Do.	(244) Maung Lun Bin	Do.	P. L. (renewal).	947	6th September 1916.	Do.
Do.	(245) Messrs. Hossain Hamadanee, Rowland Ady and R. S. Giles.	Do.	P. L. (renewal).	765	6th December 1916.	Do.
Do.	(246) Messrs. The Bombay Burma Trading Corporation, Ltd.	Do.	P. L. (renewal).	1,000	7th December 1916.	6 months.
Do.	(247) Maung Kya Pe, Maung Lu Chaw and Ma Kin.	Do.	P. L. (renewal).	358	9th December 1916.	1 year.
Do.	(248) Eu Kya Ban and Mr. A. G. Fraser.	Do.	P. L. (renewal).	584	20th December 1916.	6 months.
Do.	(249) Messrs. The London and Burmese Wolfram Co. (transferred from Messrs. Turnbulls (Glasgow), Ltd.)	Do.	P. L. (renewal).	2,409	12th January 1917.	1 year.
Do.	(250) Messrs. Steel Bros. & Co., Ltd.	Do.	P. L. (renewal).	716	1st February 1917.	Do.
Do.	(251) Messrs. Booth & Milne.	Do.	P. L. (renewal).	405	14th February 1917.	Do.
Do.	(252) Maung Sein Daing Bros. & Co.	Do.	P. L. (renewal).	276	23rd February 1917.	Do.
Do.	(253) Do.	Do.	P. L. (renewal).	717	Do.	Do.
Do.	(254) San Sino Tin	Do.	P. L. (renewal).	460	16th December 1916	6 months.
Do.	(255) Maung Sein Thwe	Do.	P. L. (renewal).	256	9th April 1917.	Do.
Do.	(256) C. Gyaw Saing	Do.	P. L. (renewal).	1,106	22nd February 1917.	Do.
Do.	(257) Maung Sein Daing	Do.	P. L. (renewal).	700	23rd March 1917.	1 year.
Do.	(258) Ong Hoe Kyin	Do.	P. L. (renewal).	605	4th April 1917.	6 months.
Do.	(259) Maung Ba Don	Do.	P. L. (renewal).	620	Do.	Do.
Do.	(260) Do.	Do.	P. L. (renewal).	282	11th May 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(261) Mr. Mahomed Aslam Khan.	All minerals (except oil).	P. L. (renewal).	392	24th March 1917.	1 year.
Do.	(262) Mr. Khoo Tun Byan.	Do.	P. L. (renewal).	322	21st March 1917.	Do.
Do.	(263) Mr. M. A. Sooratee	Do.	P. L. (renewal).	1,024	4th May 1917.	Do.
Do.	(264) Mr. Osman Musti Khan.	Do.	P. L. (renewal).	2,278	12th April 1917.	6 months.
Do.	(265) Maung Ba Thaung Bros. & Co.	Do.	P. L. (renewal).	737	23rd March 1917.	1 year.
Do.	(266) Mr. C. Soo Don	Do.	P. L. (renewal).	604	23rd April 1917.	Do.
Do.	(267) Mr. A. D. Brown	Do.	P. L. (renewal).	666	5th April 1917.	Do.
Do.	(268) Mr. A. S. Minus	Do.	P. L. (renewal).	768	27th April 1917.	6 months.
Do.	(269) Mr. Chew Lu Yin	Do.	P. L. (renewal).	870	4th May 1917.	Do.
Do.	(270) Maung Po Htin	Do.	P. L. (renewal).	460	4th April 1917.	1 year.
Do.	(271) Maung Ni	Do.	P. L. (renewal).	1,917	11th March 1917.	6 months.
Do.	(272) Messrs. Gillanders Arbuthnot & Co.	Do.	P. L. (renewal).	760	25th November 1916.	1 year.
Do.	(273) Mr. R. C. N. Twite	Do.	P. L. (renewal).	625	14th May 1917.	6 months.
Do.	(274) The Shwe Zun	Do.	P. L. (renewal).	512	20th May 1917.	Do.
Do.	(275) Ong Hoe Kyin	Do.	P. L. (renewal).	610	29th May 1917.	1 year.
Do.	(276) A. S. Mahomed	Do.	P. L. (renewal).	1,804	12th June 1917.	Do.
Do.	(277) Messrs. The Rangoon Mining Co., Ltd.	Wolfram and tin	M. L.	3,209·86	4th October 1913.	30 years.
Do.	(278) Messrs. The Wagon-Pachaung Wolfram Mines, Ltd.	Do.	M. L.	1,763·10 at Wagon.	20th July 1914.	Do.
Do.	(279) Messrs. The Hermyingyi Mining Co., Ltd.	All minerals except oil and precious stones.	M. L.	1,782·85	17th December 1918.	Do.
Do.	(280) Messrs. The Tavoy Concessions, Ltd.	Do.	M. L.	750·94 at Thingandon.	Do.	Do.
Do.	(281) Do.	Do.	M. L.	904·22 at Kadwe.	Do.	Do.

P. L.—*Prospecting License.* M. L.—*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(282) Messrs. The Wagon-Pachaung Wolfram Mines, Ltd.	Wolfram and tin	M. L.	2,162·38* at Pachaung.	5th September 1914.	30 years.
Do.	(283) Messrs. Radcliff & Co., Ltd.	All minerals except oil and precious stones.	M. L.	4,843·79	30th December 1913.	Do.
Do.	(284) Messrs. The Tavoy Concessions, Ltd.	Do.	M. L.	1,002·86 at Kalonta.	18th January 1917.	Do.
Do.	(285) Do.	Do.	M. L.	616·72 at Byaukchaung.	19th January 1917.	Do.
Do.	(286) Mr. Quah Cheng Guan.	Wolfram and tin	M. L.	199·69	16th June 1915.	Do.
Do.	(287) Oosman Musti Khan.	All minerals (except oil).	P. L.	747	10th August 1917.	6 months.
Do.	(288) Mr. C. Willison	Do.	P. L.	26	1st August 1917.	1 year.
Do.	(289) Quah Cheng Gwan	Do.	P. L.	1,003	3rd September 1917.	Do.
Do.	(290) Messrs. Finlay Fleming & Co.	Do.	P. L.	287	30th July 1917.	6 months.
Do.	(291) Maung Po Gywe	Do.	P. L.	604	6th August 1917.	1 year.
Do.	(292) Quah Cheng Tock	Do.	P. L.	2,176	10th July 1917.	Do.
Do.	(293) Do.	Do.	P. L.	988	3rd September 1917.	Do.
Do.	(294) Seinbondaung Mining Co.	Do.	P. L.	502	17th September 1917.	Do.
Do.	(295) Mr. A. R. H. Ady	Do.	P. L.	460	8th August 1917	Do.
Do.	(296) Maung Maung	Do.	P. L.	563	26th September 1917.	Do.
Do.	(297) Maung Po Gywe	Do.	P. L.	297	Do.	Do.
Do.	(298) Maung Lu Pe and Mr. A. G. Fraser.	Do.	P. L. (renewal).	780	5th December 1916.	6 months.
Do.	(299) Messrs. Steel Bros. & Co., Ltd.	Do.	P. L. (renewal).	589	16th May 1917.	1 year
Do.	(300) Ung Kyi Pe	Do.	P. L. (renewal).	614	17th May 1917.	Do.
Do.	(301) Messrs. The Bombay-Burma Trading Corporation, Ltd.	Do.	P. L. (renewal).	1,459	12th May 1917.	6 months.
Do.	(302) Do.	Do.	P. L. (renewal).	947	Do.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(303) Maung Kya Tun	All minerals (except oil).	P. L. (renewal).	307	20th May 1917.	6 months.
Do.	(304) Maung Po Mye	Do.	P. L. (renewal).	855	1st June 1917.	1 year.
Do.	(305) Messrs. Tata Sons & Co.	Do.	P. L. (renewal).	292	6th June 1917.	Do.
Do.	(306) Mahomed Aslam Khan.	Do.	P. L. (renewal).	1,536	16th June 1917.	6 months.
Do.	(307) Maung Me	Do.	P. L. (renewal).	1,280	22nd June 1917.	1 year.
Do.	(308) Khoo Zun Nee	Do.	P. L. (renewal).	739	7th June 1917.	Do.
Do.	(309) Maung Saw Hlaing	Do.	P. L. (renewal)	1,280	21st June 1917.	6 months.
Do.	(310) Do.	Do.	P. L. (renewal)	548	2nd July 1917.	Do.
Do.	(311) Ong Hoe Kyin	Do.	P. L. (renewal).	179	13th June 1917.	1 year.
Do.	(312) Ganpat Rai	Do.	P. L. (renewal).	384	16th June 1917.	6 months.
Do.	(313) Mr. Fowle	Do.	P. L. (renewal).	320	13th June 1917.	Do.
Do.	(314) The High Speed Steel Alloys, Ltd.	Do.	P. L. (renewal).	1,433	Do.	Do.
Do.	(315) Khoo Tun Byan	Do.	P. L. (renewal).	143	30th May 1917.	Do.
Do.	(316) Mr. A. E. Wallenberg	Do.	P. L. (renewal).	720	20th May 1917.	Do.
Do.	(317) Chan Kin Way	Do.	P. L. (renewal).	256	8th July 1917.	1 year.
Do.	(318) Netram Rambux	Do.	P. L. (renewal).	240	4th July 1917.	6 months.
Do.	(319) Messrs. The Bombay-Burma Trading Corporation, Ltd.	Do.	P. L. (renewal).	1,000	7th June 1917.	1 year.
Do.	(320) Ma Yin Bi	Do.	P. L. (renewal).	640	29th November 1916.	Do.
Do.	(321) Mr. Fitzherbert	Do.	P. L. (renewal)	238	24th February 1917.	6 months.
Do.	(322) Eu Kya Ban & Mr. Fraser.	Do.	P. L. (renewal).	584	20th June 1917.	Do.
Do.	(323) Mr. S. S. Halker	Do.	P. L. (renewal).	1,587	1st July 1917.	3 months.
Do.	(324) Messrs. Finlay Fleming & Co., Ltd.	Do.	P. L. (renewal).	445	7th July 1917.	6 months.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(325) San Sine Tin	All minerals (except oil).	P. L. (renewal).	911	9th August 1917.	6 months.
Do.	(326) Messrs. Hitakari & Co.	Do.	P. L. (renewal).	589	28th May 1917.	Do.
Do.	(327) Maung Mya Pe	Do.	P. L. (renewal).	537	26th June 1917.	Do.
Do.	(328) Maung Sein Khaing.	Do.	P. L. (renewal).	640	8th July 1917.	Do.
Do.	(329) Maung Sein Khaing.	Do.	P. L. (renewal).	682	23rd May 1917.	Do.
Do.	(330) Mr. A. R. H. Ady	Do.	P. L. (renewal).	620	6th July 1917.	Do.
Do.	(331) Maung E. Zin	Do.	P. L. (renewal).	435	15th August 1917.	3 months.
Do.	(332) Mr. A. Fraser	Do.	P. L. (renewal).	922	22nd July 1917.	6 months.
Do.	(333) Maung Paw Tun	Do.	P. L. (renewal).	450	19th April 1917.	Do
Do.	(334) Maung Min Gyaw	Do.	P. L. (renewal).	1,182	8th August 1917.	1 year.
Do.	(335) Maung Mo Thu	Do.	P. L. (renewal).	1,536	14th June 1917.	6 months.
Do.	(336) Maung Khine	Do.	P. L. (renewal).	809	24th August 1917.	Do.
Do.	(337) Maung Sein Thwe	Do.	P. L. (renewal).	589	19th August 1917.	Do.
Do.	(338) Mr. Fitzherbert	Do.	P. L. (renewal).	238	4th August 1917.	Do.
Do.	(339) Maung Shwe Gaing	Do.	P. L. (renewal).	512	23rd September 1917.	Do.
Do.	(340) Ma Mya Yin	Do.	P. L.	1,039	21st December 1917.	1 year.
Do.	(341) Mr. G. Willison	Do	P. L.	548	22nd October 1917.	Do.
Do.	(342) San Sine Tin	Do.	P. L.	620	7th November 1917.	Do.
Do.	(343) Mr. J. J. Page	Do.	P. L.	701	19th October 1917.	Do.
Do.	(344) The Hon'ble Mr. Lim Chin Tsong.	Do.	P. L.	320	12th October 1917.	Do.
Do.	(345) Eu Kya Ban	Do.	P. L.	640	28th December 1917.	Do.
Do.	346) Mr. A. R. H. Ady	Do.	P. L.	512	28th November 1917.	6 months.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(347) Maung Me . .	All minerals (except oil).	P. L. .	358	30th November 1917.	1 year.
Do. .	(348) Mr. G. Willison .	Do. .	P. L. .	317	26th November 1917.	Do.
Do. .	(349) Messrs. Tata Sons & Co.	Do. .	P. L. (renewal).	780	9th June 1917.	6 months.
Do. .	(350) Mr. A. E. Wallenberg.	Do. .	P. L. . (renewal).	1,422	21st June 1917.	Do.
Do. .	(351) Maung Po Swo .	Do. .	P. L. . (renewal).	488	22nd July 1917.	Do.
Do. .	(352) C. Gyaw Saing .	Do. .	P. L. . (renewal).	1,106	22nd August 1917.	1 year.
Do. .	(353) Maung Gun .	Do. .	P. L. . (renewal).	768	3rd September 1917.	6 months.
Do. .	(354) Mr. A. E. Wallenberg.	Do. .	P. L. . (renewal).	1,600	13th September 1917.	Do.
Do. .	(355) Mr. R. C. N. Twite	Do. .	P. L. . (renewal).	460	22nd September 1917.	Do.
Do. .	(356) Maung Ba Maung	Do. .	P. L. . (renewal).	1,920	24th September 1917.	Do.
Do. .	(357) Messrs. The High Speed Steel Alloys Mining Co., Ltd.	Do. .	P. L. . (renewal).	256	26th September 1917.	Do.
Do. .	(358) Ma Mya Yin .	Do. .	P. L. . (renewal).	1,075	Do. .	Do.
Do. .	(359) Maung Po Hnan	Do. .	P. L. . (renewal).	640	Do. .	Do.
Do. .	(360) Lim Kyee Yan .	Do. .	P. L. . (renewal).	161·28	28th September 1917.	1 year.
Do. .	(361) Maung Sein Thwe	Do. .	P. L. . (renewal).	256	9th October 1917.	6 months
Do. .	(362) Mr. S. S. Halkar .	Do. .	P. L. . (renewal).	681	1st October 1917.	Do.
Do.	(363) Maung Tun Mya .	Do. .	P. L. . (renewal).	988	9th September 1917.	1 year.
Thaton .	(364) Ma Nyein . .	Do. .	P. L. .	608	2nd January 1917.	Do.
Do.	(365) Mr. H. F. Singleton and Messrs. Binning & Co.	Do. .	P. L. .	512	26th January 1917.	Do.
Do. .	(366) Mr. J. W. Darwood	Do. .	P. L. .	1,145·6	22nd January 1917.	Do.
Do. .	(367) Ma Nyein . .	Do. .	P. L. .	576	18th January 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thaton .	(368) Maung Tun Hla .	All minerals (except oil).	P. L. .	1,241·6	25th January 1917.	1 year.
Do. .	(369) Maung Ba Si .	Do. .	P. L. .	601·6	10th February 1917.	Do.
Do. .	(370) Lim Kar Chang .	Do. .	P. L. .	3,238·4	1st March 1917.	Do.
Do. .	(371) Mr. A. Samed .	Do. .	P. L. .	9·50	3rd March 1917.	Do.
Do. .	(372) Li Ah Lye . .	Do. .	P. L. . (renewal).	640	18th December 1916.	Do.
Do. .	(373) Ma Thein Zin .	Do. .	P. L. . (renewal).	320	14th February 1917.	Do.
Do. .	(374) Mr. C. H. Stork .	Do. .	P. L. . (renewal).	819·2	17th February 1917.	Do.
Do. .	(375) U Pan Dwe and Ma Khin, *alias* Messrs. Bah Too.	Do. .	P. L. . (renewal).	2,649·6	10th March 1917.	Do.
Do. .	(376) Dr. Shaw Loo .	Do. .	P. L. .	1,536	4th April 1917.	Do.
Do. .	(377) Mr. P. M. Pillay .	Do. .	P. L. .	1,491·2	11th April 1917.	Do.
Do. .	(378) Maung Pu . .	Do. .	P. L. .	1,574·4	Do. .	Do.
Do. .	(379) The Hon'ble Mr. Lim Chin Tsong.	Do. .	P. L. .	1,318·4	22nd May 1917.	Do.
Do. .	(380) Do. .	Do. .	P. L. .	396·8	18th April 1917.	Do.
Do. .	(381) Maung Ba Tin .	Do. .	P. L. .	672	26th April 1917.	Do.
Do. .	(382) Mr. F. A. Boog .	Do. .	P. L. .	3,968	25th April 1917.	Do.
Do. .	(383) Mr. A. D. Keith .	Do. .	P. L. .	5,657·6	Do. .	Do.
Do. .	(384) The Hon'ble Mr. Lim Chin Tsong.	Do. .	P. L. .	825·6	15th April 1917.	Do.
Do. .	(385) Mr. F. A. Boog .	Do. .	P. L. .	4,313·6	Do. .	Do.
Do. .	(386) Maung Shan Byu	Do. .	P. L. .	4,640	10th April 1917.	Do.
Do. .	(387) Mr. Tan Too .	Do. .	P. L. .	518·4	5th June 1917.	Do.
Do. .	(388) Mr. L. Hong Seng	Do. .	P. L. .	678·4	15th March 1917.	Do.
Do. .	(389) Mr. C. H. Noyce .	Do. .	P. L. .	2,931·2	2nd May 1917.	Do.
Do. .	(390) Mr. C. R. Connell	Do. .	P. L. .	3,513·6	27th April 1917.	Do.

P. L.=*Prospecting License.* M. L.—*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thaton .	(391) Mr. C. R. Connel .	All minerals (except oil).	P. L. .	2,444·8	25th April 1917.	1 year.
Do. .	(392) The Hon'ble Mr. Lim Chin Tsong.	Do.	P. L. .	864	19th May 1917.	Do.
Do. .	(393) Mr. Tan Kim Chye	Do. .	P. L. .	51·2	21st May 1917.	Do.
Do. .	(394) Maung Ni . .	Do. .	P. L. .	1,350·4	19th May 1917.	Do.
Do. .	(395) Maung Pu . .	Do. .	P. L. .	563·2	25th April 1917.	Do.
Do. .	(396) Mr. L. Ah Choy .	Do. .	P. L. .	563·2	19th May 1917.	Do.
Do. .	(397) Mr. Tan Kim Chye	Do. .	P. L. .	4,064	28th May 1917.	Do.
Do. .	(398) Maung Ni . .	Do. .	P. L. .	953·6	24th May 1917.	Do.
Do. .	(399) Mr. C. A. Meredith	Do. .	P. L. .	1,305·6	7th June 1917.	Do.
Do. .	(400) Maung Shwe Goh	Do. .	P. L. .	1,049·6	6th June 1917.	Do.
Do. .	(401) Maung Kaing .	Do. .	P. L. . (renewal).	678·4	14th February 1917.	Do.
Do. .	(402) Mr. H. E. Singleton.	Do. .	P. L. . (renewal).	1,657·6	21st February 1917.	Do.
Do. .	(403) Mr. A. Kader .	Do. .	P. L. . (renewal).	499·2	1st April 1917.	Do.
Do. .	(404) Maung Pu . .	Do. .	P. L. . (renewal).	108·8	7th April 1917.	Do.
Do. .	(405) Mr. A. J. Salvador	Do. .	P. L. . (renewal).	851·2	Do. .	Do.
Do. .	(406) Messrs. A. V. Joseph & Co.	Do. .	P. L. . (renewal).	524·8	2nd May 1917.	Do.
Do. .	(407) Maung Chit Maung	Do. .	P. L. . (renewal).	1,836·8	11th April 1917.	Do.
Do. .	(408) Mr. C. Soo Don .	Do. .	P. L. . (renewal).	876·8	2nd February 1917.	Do.
Do. .	(409) Mr. C. R. Connell	Do. .	P. L. .	1,881·6	29th May 1917.	Do.
Do. .	(410) Ko Chang Kaing .	Do. .	P. L. .	889·6	26th April 1917.	Do.
Do. .	(411) M. Ah Khee .	Do. .	P. L. .	563·2	27th June 1917.	Do.
Do. .	(412) Mr. C. P. Vheland	Mineral oil . .	P. L. .	819·2	14th July 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thaton .	(413) Mr. P. M. Pillay .	Mineral oil .	P. L. .	29·44	20th June 1917.	1 year.
Do. .	(414) Maung Pe Gyi .	All minerals (except oil).	P. L. .	1,020	23rd July 1917.	Do.
Do. .	(415) U. Shan Byu	Do. .	P. L. .	2,144	23rd March 1917.	Do.
Do. .	(416) Maung Tun Hla .	Do. .	P. L. .	1,952	24th May 1917.	Do.
Do. .	(417) Maung San Dun .	Do. .	P. L. .	1,075·2	12th July 1917.	Do.
Do. .	(418) Mr. C. A. Meredith	Do. .	P. L. .	236·5	27th June 1917	Do.
Do. .	(419) U. Pan Dwe .	Do. .	P. L. .	128	20th June 1917.	Do.
Do. .	(420) U Po Ngwe . .	Do. .	P. L. .	2,048	5th June 1917.	Do.
Do. .	(421) Tan Kin Chye .	Do. .	P. L. .	601·2	31st August 1917.	Do.
Do. .	(422) Ma Pyu Pyu .	Do. .	P. L. .	1,254·4	14th July 1917.	Do.
Do. .	(423) U Po Ngwe . .	Do. .	P. L. (renewal).	729·6	7th August 1917.	6 months.
Do. .	(424) U Ba Wet . .	Do. .	P. L. (renewal).	1,190·4	16th August 1917.	1 year.
Do. .	(425) M. A. Kader .	Do. .	P. L. .	640	18th October 1917.	Do.
Do. .	(426) The Hon'ble Mr. Lim Chin Tsong.	Do. .	P. L. .	6,365	17th September 1917.	Do.
Do. .	(427) Maung Ba Si .	Do. .	P. L. .	1,260·8	7th August 1917	Do.
Do. .	(428) Lim Tha Nyein .	Do. .	P. L. .	2,003·2	31st July 1917.	Do.
Do. .	(429) Mr. C. A. Meredith	Do. .	P. L. .	3,174·4	12th July 1917	Do.
Do. .	(430) M. Hashim . .	Do. .	P. L.	640	27th September 1917	Do.
Do. .	(431) M. Ah Khee .	Do. .	P. L. (renewal).	467·2	20th July 1917.	2 years.
Do. .	(432) Maung Pu . .	Do. .	P. L. (renewal)	106·8	22nd November 1917.	6 months.
Thayetmyo.	(433) Messrs The Twinzas Oil Co., Ltd.	Mineral oil	P. L.	1,[illegible]0 Blocks Nos. 13, 20 and 2[illegible] of the Minbu Oil Field	21st December 1916	1 year

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thayetmyo.	(434) Mr. B. Cowasjee	Mineral oil	P. L.	1,123·2 Blocks 1, 2 and 8 and the eastern half of block 9 of the Minhla Oil Field.	21st December 1916.	1 year.
Do.	(435) Messrs. The Burma Oil Co., Ltd.	Do.	P. L.	5,120 Eastern halves of blocks Nos. 18, 25, 28 and 39, western halves of blocks Nos. 19 and 30 and the whole of blocks 24, 29, 33, 34, and 40 of the Minhla Oil Field.	Do.	Do.
Do.	(436) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do.	P. L.	2,868·9 Blocks Nos. 3 and 4 excluding area held by the B. B. P. Co. in block No. 4, blocks Nos. 16 and 17; western half of block 18 and eastern half of block 19 of the Minhla Oil Field.	Do.	Do.
Do.	(437) Messrs. The British-Burma Petroleum Co., Ltd.	Do.	P. L. (renewal).	94·72 Block 4 of the Minhla Oil Field.	23rd December 1916.	Do.
Do.	(438) Messrs. The London-Rangoon Trading Co., Ltd.	Do.	P. L.	2,560 (Blocks Nos. 26 and 27, E½ of 30, W½ of 9, 25 and 28 of the Minhla Oil Field.	9th March 1917.	Do.
Do.	(439) Do.	Do.	P. L.	10,240	30th May 1917.	Do.
Do.	(440) Messrs. The Nath Singh Oil Co., Ltd.	Do.	P. L.	4,800	18th October 1917.	Do.
Do.	(441) Mr. H. V. Murray	Do.	P. L.	3,200	13th November 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Leas*

BURMA—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Upper Chindwin.	(442) Messrs. Osman Muste Khan & Co.	Mineral oil .	P. L. .	3,840	18th December 1916.	1 year.
Do. .	(443) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. . (renewal).	12,800	12th September 1916.	Do.
Do. .	(444) Do. .	Do. .	P. L. .	3,200	24th May 1917.	Do.
Yamethin .	(445) Messrs. Becchardass Maneckchand Kharwar.	Lead . .	P. L. .	2,560	20th April 1917.	Do.

CENTRAL PROVINCES.

Balaghat .	(446) Khan Bahadur Byramji Pestonji.	Manganese .	P. L. .	280	7th February 1917.	1 year.
Do. .	(447) Indian Manganese Company, Limited.	Do. .	P. L. .	1	18th January 1917.	Do.
Do. .	(448) Do. .	Do. .	P. L. .	153	Do. .	Do.
Do. .	(449) Babu Kripashankar.	Do. .	P. L. . (renewal).	271	5th February 1917.	6 months
Do. .	(450) Do. .	Do. .	P. L. . (renewal).	350	8th January 1917.	Do.
Do. .	(451) Khan Bahadur Byramji Pestonji.	Do. .	M. L. .	346	28th April 1917.	30 years.
Do. .	(452) Seth Gowardhandas.	Do. .	P. L. .	20	5th May 1917.	1 year.
Do. .	(453) Babu Kripashankar.	Do. .	P. L. . (renewal).	272	5th August 1917.	6 months.
Do. .	(454) Indian Manganese Company, Limited.	Do. .	P. L. .	60	28th August 1917.	1 year.
Do. .	(455) Khan Bahadur Byramji Pestonji.	Do. .	M. L. .	4	27th June 1917.	5 years.
Do.	(456) Do. .	Do. .	M. L. .	48	13th August 1917.	Do.
Do.	(457) Babu Kripashankar.	Do. .	P. L. . (renewal).	38	29th August 1917.	6 months.
Do.	(458) Khan Bahadur Byramji Pestonji.	Do. .	P. L. .	171	13th October 1917.	1 year.
Do. .	(459) Babu Kripashankar.	Do. .	P. L. .		Do. .	Do.
Do. .	(460) Pandit Rewashankar.	Do. .	P. L. .	35	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat	(461) Messrs. Ramper-shad Lakshminarayan.	Manganese	P. L.	2	17th December 1917.	1 year.
Do.	(462) Babu Kripashankar.	Do.	P. L.	171	13th October 1917.	Do.
Do.	(463) Messrs. Tata Sons & Co.	Bauxite	P. L.	63	31st December 1917.	Do.
Do.	(464) Do.	Do.	P. L.	107	Do.	Do.
Do.	(465) Do.	Do.	P. L.	241	Do.	Do.
Do.	(466) Do.	Do.	P. L.	96	21st December 1917.	Do.
Bhandara	(467) Nagpur Manganese Mining Syndicate, Ltd.	Manganese	M. L.	18	23rd January 1917.	10 years.
Do.	(468) Messrs. Lalbehari and Ramcharan.	Do.	M. L.	25	15th December 1916.	Do.
Do.	(469) Seth Gowardhandas.	Do.	M. L.	62	12th December 1916.	30 years.
Do.	(470) Hon'ble Dewan Bahadur Sir Kasturchand Daga, K.C.I.E.	Do.	M. L.	87	18th December 1916.	5 years.
Do.	(471) Khan Bahadur Byramji Pestonji.	Do.	M. L.	13	21st February 1917.	Do.
Do.	(472) Seth Gowardhandas.	Do.	P. L.	232	15th January 1917.	1 year.
Do.	(473) Seth Mahadeo	Do.	P. L.	29	27th March 1917.	Do.
Do.	(474) Pandit Rewashankar.	Do.	P. L.	47	3rd February 1917.	Do.
Do.	(475) Seth Gowardhandas.	Do.	P. L.	30	21st June 1917.	Do.
Do.	(476) Do.	Do.	P. L.	50	Do.	Do.
Do.	(477) Seth Mahadeo	Do.	P. L. (renewal).	8	26th September 1917.	Do.
Do.	(478) Do.	Do.	P. L. (renewal)	38	15th June 1916.	Do.
Do.	(479) Do.	Do.	P. L. (renewal).	30	26th August 1917.	Do.
Do.	(480) Do.	Do.	P. L.	348	13th September, 1917.	Do.
Do.	(481) Do.	Do.	P. L.	611	Do.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant	Area in acres.	Date of commencement.	Term.
Bhandara .	(482) Seth Gowardhandas.	Manganese .	M. L. .	19	19th April 1917.	Will expire with the original lease dated the 5th March 1916, to which it is supplementary
Do. .	(483) Seth Shriram .	Do. . .	P. L. .	38	9th August 1917.	1 year
Do. .	(484) Seth Jagannath .	Do .	P. L. .	213	13th August 1917	Do
Do. .	(485) Seth Shriram .	Do. .	P. L. .	274	29th September 1917	Do
Do. .	(486) Messrs. Lal Behari and Ramcharan.	Do. .	P. L. (renewal)	16	11th July 1917.	Do
Do. .	(487) Seth Mahadeo .	Do .	P. L .	45	30th September 1917.	Do
Do. .	(488) Seth Shriram .	Do. .	P. L. .	47	29th September 1917.	Do.
Do. .	(489) Seth Gowardhandas.	Do. .	M. L. .	29	17th October 1917.	4 years
Do. .	(490) Seth Shriram .	Do. .	P. L. .	89	3rd December 1917	1 year.
Do.	(491) Do	Do. .	P. L. .	29	13th October 1917.	Do.
Bilaspur .	(492) Tata Iron and Steel Co., Ltd.	Iron ore and other minerals (Dolomite and limestone).	P. L. .	6,799	28th May 1917	Do
Chanda .	(493) Messrs. H. Verma and Kanhaiyalal.	Coal . . .	M. L. .	1,221	5th February 1917.	Will expire with the original lease dated the 30th October 1915 to which it is supplementary.
Do. .	(494) Mr. Padamsy Narsibhoy.	Do. . . .	P. L. .	3,827	17th May 1917	1 year.
Do. .	(495) Do. .	Do. . . .	P. L. .	400	17th June 1917.	Do
Do. .	(496) Do. .	Do. . . .	P. L. .	640	17th May 1917.	Do

P. L.=*Prospecting License.* M. L.=*Mining Lease*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chanda .	(497) Messrs. Hashambhoy & Sons.	Coal . . .	P. L. .	2,439	10th October 1917.	1 year.
Do. .	(498) Mr. Padamsy Narsibhoy.	Do. . . .	P. L. .	70	26th November 1917.	Do.
Chhindwara	(499) Khan Bahadur Byramji Pestonji.	Manganese . .	P. L. .	134	27th January 1917.	Do.
Do. .	(500) Do. .	Do. . .	M. L. .	83	21st February 1917.	5 years.
Do. .	(501) Messrs. H. Verma and Kanhaiyalal.	Coal . . .	P. L. .	437	21st May 1917	1 year.
Do. .	(502) Rai Bahadur Bishesar Das Daga.	Manganese . .	P. L. .	39	2nd April 1917.	Do.
Do. .	(503) The Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. .	129	3rd April 1917.	Do.
Do.	(504) Messrs. H. Verma and Kanhaiyalal.	Coal . . .	P. L. .	146	4th October 1917.	Do.
Do. .	(505) Do. .	Do. . .	P. L. .	370	19th December 1917.	Do.
Do. .	(506) Indian Manganese Co.	Manganese . .	M. L. .	21	17th October 1917.	Will expire with the original lease dated the 6th February 1904 to which it is supplementary.
Drug .	(507) Messrs. Bahmanshah Fouzdar Bros.	Bauxite, lead, silver, gold, cobalt and copper.	M. L. .	3	2nd November 1917.	Will expire with the original lease, dated the 20th June, 1910, to which it is supplementary.
Jubbulpore	(508) Messrs Burn & Co.	Coal . . .	P. L. .	1,127	29th January 1917.	1 year.
Do	(509) Mr. P. C. Dutt .	Bauxite . .	P. L. .	443	5th January 1917.	Do.
Do.	(510) Do. .	Manganese . .	P. L. .	55	22nd May 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jubbulpore	(511) Mr. P. C. Dutt .	Manganese	M. L. .	19	2nd April 1917.	Will expire with the original lease, dated the 14th September 1915, to which it is supplementary.
Do. .	(512) Do. .	Do. .	P. L.	82	Do. .	1 year.
Do. .	(513) Do. .	Bauxite and iron	P. L. (renewal).	148	22nd October 1916.	Do.
Do. .	(514) Do. .	Bauxite . .	M. L. .	52	12th July 1917.	30 years.
Do. .	(515) Do. .	Bauxite and iron oxide.	P. L. .	404	9th August 1917.	1 year.
Do. .	(516) Do. .	Coal . . .	P. L. .	384	23rd July 1917.	Do.
Do. .	(517) Do. .	Manganese, iron, thallium, bauxite, vanadium, caesium, cerium, columbium, didymium, erbium, gallium, germanium, indium, lithium, niobium, rubidium, tantalum, thorium, uranium, yttrium and zirconium.	P. L. .	566	30th November 1917.	Do.
Do. .	(518) Do. .	Bauxite lead, gold, barytes, silver. and copper.	P. L. .	212	5th November 1917.	Do.
Do. .	(519) Do. .	Bauxite and iron	P. L. .	653	Do. .	Do.
Do. .	(520) Do. .	Manganese, iron, Bauxite, nickel, cobalt, cadmium, molybdenum, thallium, vanadium, titanium, copper, caesium, cerium, columbium, didymium, erbium, gallium, germanium, indium, lithium, niobium rubidium, tantalum, thorium, uranium, yttrium and zirconium.	P. L. .	293	21st December 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jubbulpore	(521) Khan Bahadur Byramji Pestonji.	Manganese . .	P. L. .	75	7th December 1917.	1 year.
Do. .	(522) Messrs. Burn & Co.	Bauxite . .	P. L. .	4,150	17th November 1917.	Do.
Do. .	(523) Mr. S. R. Dutt .	Bauxite and barytes.	P. L. .	154	7th December 1917.	Do.
Nagpur .	(524) Messrs. H Verma and Kanhaiyalal.	Manganese . .	M. L. .	171	15th January 1917.	30 years.
Do. .	(525) Mr. Lakshman Damodhar Lele.	Do . .	M. L. .	59	28th November 1916.	Do.
Do. .	(526) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	489	16th January 1917.	1 year.
Do. .	(527) Messrs. Goredutt, Ganeshlal and M. D'Costa.	Do. . .	P. L. .	44	1st May 1917	Do.
Do. .	(528) Messrs. Bahmansha Fouzdar Bros.	Do. . .	P. L. .	184	21st April 1917.	Do.
Do. .	(529) Central India Mining Co., Ltd.	Do. . .	P. L. .	545	27th April 1917.	Do.
Do. .	(530) Messrs. Bahmansha Fouzdar Bros.	Do. . .	P. L. .	30	19th September 1917.	Do.
Do. .	(531) Seth Gowardhandas	Mica . . .	P. L. .	30	21st August 1917.	Do.
Do. .	(532) Nagpur Manganese Mining Syndicate.	Manganese . .	P. L. .	53	20th July 1917.	Do.
Do. .	(533) Rao Sahib D. Lakshminarayan.	Manganese and pyrolusite	P. L. .	20	31st August 1917.	Do.
Do. .	(534) Central India Mining Co., Ltd.	Manganese . .	P. L. .	7	9th November 1917.	Do.
Do. .	(535) Do .	Do. . .	P. L. .	475	7th December 1917.	Do
Do. .	(536) Do. .	Do. .	P. L. .	153	18th October 1917.	Do.
Do. .	(537) Do. .	Do. . .	P. L. .	240	Do. .	Do.
Do .	(538) Mir Aslam Khan .	Do. . .	P. L. .	7	9th November 1917.	Do.
Do .	(539) Rai Bahadur Bissessardas Daga.	Do. . .	P. L. .	81	7th December 1917.	Do.
Do	(540) Do. .	Do. . .	P. L.	70	21st November 1917.	Do.

P. L.=*Prospecting License* M. L.=*Mining Lease*

CENTRAL PROVINCES—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur	(541) Mir Aslam Khan	Manganese	P. L.	629	12th October 1917.	1 year.
Do.	(542) Messrs. Bahmansha Fouzdar Bros.	Do.	P. L.	32	9th November 1917.	Do.
Do.	(543) Mir Aslam Khan	Do.	P. L.	442		Do.
Do.	(544) Mr N. Venkat Ramannah.	Do.	P. L.	111	21st September 1917.	Do.
Yeotmal	(545) Mulla Hasan Ali Nathubhoy.	Coal	M. L.	1,206	26th January 1917.	30 years.
Do.	(546) Do.	Do.	M. L.	563	Do.	Do.
Do.	(547) Do.	Do.	M. L.	1,291	17th February 1917.	Do.

MADRAS.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Coimbatore	(548) Messrs. Startin & Co. of London.	Mica	P. L.	4·37	24th March 1917.	1 year.
Do.	(549) Messrs. Startin & Co.	Do.	P. L.	9·34	2nd August 1917.	Do.
Kurnool	(550) A. Ghose, Esq.	Barytes	P. L.	62·57	27th February 1917.	Do.
Do.	(551) Do.	Do.	P. L.	20·85	18th May 1917.	Do.
Do.	(552) Do.	Do.	P. L.	66·70	4th August 1917.	Do.
Do.	(553) Do.	Do.	P. L.	58·82	18th July 1917.	Do.
Nellore	(554) P. Krishnasami Mudaliyar.	Mica	M. L.	174·76	10th December 1913.	30 years.
Do.	(555) Messrs. F. F. Chrestien & Co.	Do.	M. L.	2·32	28th November 1916.	Do.
Do.	(556) P. Venkatasami Chetti.	Do.	P. L.	6·74	10th January 1917.	1 year.
Do.	(557) Indupur Subbarami Reddi.	Do.	P. L.	31·26	26th June 1917.	Do.
Do.	(558) V. K. M. K. R. Karuppan Chetti.	Do.	P. L.	5	2nd March 1917.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

MADRAS—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore .	(559) K. Venkataramaniah	Mica . . .	P. L. .	15	1st April 1917.	1 year.
Do. .	(560) Khan Bahadur Muhammad Safdar Hussain.	Do. . . .	M. L. .	344·54	1st April 1914.	30 years.
Do. .	(561) M. R. M. A. Subramania Chettiar.	Do. . . .	M. L. .	34·71	5th August 1911.	Do.
Do. .	(562) B. Venkata Subba Reddi.	Do. . . .	P. L. .	17·76	1st September 1917.	1 year.
Do. .	(563) P. Venkataswami Chetti.	Do. . . .	P. L. .	48·28	9th April 1917.	Do.
Do. .	(564) V. K. M. K. R. Karuppan Chetti.	Do. . . .	P. L. .	64·02	28th July 1917.	Do.
Do. .	(565) I. Subbarami Reddi	Do. . . .	P. L. .	30·09	15th August 1917.	Do.
Do. .	(566) The Sankara Mining Syndicate.	Do. . . .	M. L. .	136·30	1st December 1905.	30 years.
Do. .	(567) A. Govindu Reddi	Do. . . .	P. L. .	26·58	20th October 1917.	1 year.
Do. .	(568) N. Raghavalu Nayakkar.	Do. . . .	P. L. .	11·96	5th December 1917.	Do.
Do. .	(569) V. K. M. K. R. Karuppan Chetti.	Do. . . .	P. L. .	24·62	1st December 1917.	Do.
Do. .	(570) N. Raghavalu Nayakkar.	Do. . . .	P. L. .	9·41	5th October 1917.	Do.
Do. .	(571) Moolji Govindji .	Do. . . .	P. L. .	20	15th October 1917.	Do.
Trichinopoly	(572) Messrs. T. Stanes & Co., Ltd., Coimbatore.	Phosphatic nodules	P. L. .	430·69	23rd June 1917.	Do.

PUNJAB.

Attock .	(573) Attock Oil Co., Ltd.	Mineral oil . .	P. L. .	1,280	5th June 1917.	1 year.
Shahpur .	(574) The Burma Oil Co., Ltd.	Do. . .	P. L. .	4,992	10th July 1917.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

SUMMARY.

Province.	Prospecting Licenses.	Mining Leases.	Total of each Province.
Assam	4	2	6
Baluchistan	3	4	7
Bihar and Orissa	21	14	35
Bombay	4	1	5
Burma	380	12	392
Central Provinces	81	21	102
Madras	20	5	25
Punjab	2	..	2
Total of each kind and Grand Total 1917	515	59	574
TOTAL OF 1916	482	50	532

CLASSIFICATION OF LICENSES AND LEASES.

TABLE 27.—*Prospecting Licenses and Mining Leases granted in Assam during 1917.*

DISTRICT.	1917.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Cachar	1	16,000	Mineral oils
Lakhimpur	1	8,238·08	Coal.
Sylhet	2	14,547·2	Mineral oils.
TOTAL	4	...	
Mining Leases.			
Khasi and Jaintia Hills	1	1,920	Metallic ores.
Lakhimpur	1	2,227·2	Coal, iron, slate and shale.
TOTAL	2	...	

TABLE 28.—*Prospecting Licenses and Mining Leases granted in Baluchistan during 1917.*

DISTRICT.	1917.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Kalat	3	58,240	Oil.

TABLE 28.—*Prospecting Licenses and Mining Leases granted in Baluchistan during 1917.*

DISTRICT.	1917.		
	No.	Area in acres.	Mineral.
Mining Leases.			
Quetta Pishin	1	80	Chromite.
Do	1	80	Coal
Sibi	2	96·46	Do.
TOTAL	4	...	

TABLE 29.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during 1917.*

DISTRICT.	1917.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Hazaribagh	5	504	Mica
Santal Parganas	2	10,239·76	Coal.
Singhbhum	5	2,025·5	Chromite.
Do.	1	11·90	Yellow ochre.
Do.	3	36,032	Manganese and iron ore
Do.	1	1,330	Galena, gold and other kindred minerals
Do.	1	75·90	Manganese.
Do.	1	150	Red ochre.
Do.	1	56	Iron ore.
Do.	1	4·60	Yellow and red ochre
TOTAL	21	...	

TABLE 29—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during 1917.*

DISTRICT.	1917. No.	1917. Area in acres.	1917. Mineral.
Mining Leases.			
Gya	1	1,557·05	Mica.
Hazaribagh	1	70	Do.
Sambalpur	1	1,300	Coal.
Santal Parganas	5	17·13	Do.
Singhbhum	3	1,532·30	Chromite.
Do.	1	800	Iron-ore.
Do.	1	1,267·2	Manganese and iron ore.
Do.	1	1	Gold.
TOTAL	14	...	

TABLE 30.—*Prospecting Licenses and Mining Leases granted in Bombay during 1917.*

DISTRICT.	1917. No.	1917. Area in acres.	1917. Mineral.
Prospecting Licenses.			
Dharwar (also in Kanara district)	1	1,143	Galena.
Kaira	1	301·95	Manganese and aluminium.
Panch Mahals.	1	45·5	Manganese.
Sukkur	1	6,008	Mineral oil.
TOTAL	4	...	
Mining Leases.			
Panch Mahals	1	680·22	Manganese ore.

TABLE 31.—*Prospecting Licenses and Mining Leases granted in Burma during 1917.*

District.	1917. No.	1917. Area in acres.	1917. Mineral.

Prospecting Licenses.

District.	No.	Area in acres.	Mineral.
Akyab	2	9,060	Mineral oil.
Amherst	12	10,133·2	All Minerals (except oil).
Bhamo	1	5,516·8	All minerals (except oil and jade).
Katha	1	24,320	Tin, wolfram, silver, copper, lead, zinc and gold.
Lower Chindwin	3	2,940	All minerals (except oil).
Do.	3	3,040	Mineral oil.
Mergui	26	27,420·46	All minerals (except oil)
Do.	2	82·92	Tin.
Do.	3	3,383·32	Wolfram and tin.
Do.	1	2,626·56	Wolfram.
Minbu	2	2,890·24	Mineral oil.
Myingyan	2	11,790	Do.
Myitkyina	1	1,132·8	Gold and platinum.
Do.	1	3,200	Gold and iridio-platinum.
Do.	2	3,571·2	Gold.
Northern Shan States	2	3,200	Iron.
Do	2	5,760	Coal.
Do.	1	3,200	Gold, silver, iron and zinc.
Pakokku	7	17,402·80	Mineral oil.
Prome	2	3,449·6	Do.
Ruby Mines	1	640	Copper.
Salween	1	3,840	All minerals (except oil).
Shwebo	2	4,704	Mineral oil.
Southern Shan States	4	2,787·93	Wolfram
Do.	1	2,560	Lead.
Do.	9	11,965	All minerals (except oil).
Do.	3	9,560	Gold.
Tavoy	201	147,824·28	All minerals (except oil).
Thaton	68	98,825·5	All minerals (except oil).
Do.	1	29·44	Mineral oil.
Thayetmyo	9	31,916·82	Do.
Upper Chindwin	3	19,840	Do.
Yamethin	1	2,560	Lead.
TOTAL	380		

TABLE 31—*Prospecting Licenses and Mining Leases granted in Burma during 1917*—contd.

DISTRICT	1917 No.	1917 Area in acres.	1917 Mineral.
Mining Leases.			
Minbu	1	19	Mineral oil.
Southern Shan States	1	2,680	Lead, copper and silver.
Tavoy	4	7,335·03	Wolfram and tin.
Do.	6	10,081·38	All minerals except oil and precious stones.
TOTAL	12		

TABLE 32.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1917.*

DISTRICT	1917. No.	1917. Area in acres.	1917. Mineral.
Prospecting Licenses.			
Balaghat	14	2,135	Manganese.
Do.	4	507	Bauxite.
Bhandara	18	2,274	Manganese.
Bilaspur	1	6,799	Iron ore and other minerals (Dolomite and Limestone).
Chanda	5	7,376	Coal.
Chindwara	3	302	Manganese.
Do.	3	953	Coal.
Jubbulpore	2	1,511	Do.
Do.	2	4,602	Bauxite.
Do.	3	212	Manganese.
Do.	2	801	Bauxite and iron.
Do.	1	404	Bauxite and iron oxide
Do.	1	566	Manganese, iron, bauxite, and all metals of the rare earth.

TABLE 32—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1917*—contd.

DISTRICT.	1917. No.	1917. Area in acres.	1917. Mineral.
Prospecting Licenses—*contd.*			
Jubbulpore	1	212	Bauxite, lead, gold, barytes, silver and copper.
Do.	1	293	Manganese, iron, bauxite, nickel, cobalt, cadmium, molybdenum, titanium copper and minerals of the rare earths.
Do.	1	154	Bauxite and barytes.
Nagpur	17	3,592	Manganese.
Do.	1	39	Mica.
Do.	1	20	Manganese and pyrolusite
TOTAL	81		
Mining Leases.			
Balaghat	3	398	Manganese.
Bhandara	7	253	Do.
Chanda	1	1,221	Coal.
Chindwara	2	104	Manganese.
Drug	1	3	Bauxite, lead, silver, gold, cobalt and copper.
Jubbulpore	1	19	Manganese.
Do.	1	52	Bauxite.
Nagpur	2	230	Mangane
Yeotmal	3	3,060	Coal.
TOTAL	21		

TABLE 33.—*Prospecting Licenses and Mining Leases granted in Madras during 1917.*

District.	1917. No.	1917. Area in acres.	1917. Mineral.
Prospecting Licenses.			
Coimbatore	2	13·71	Mica.
Kurnool	4	208·94	Barytes.
Nellore	13	304·63	Mica.
Trichinopoly	1	430·69	Phosphatic nodules.
TOTAL	20		
Mining Leases.			
Nellore	5	692·63	Mica.

TABLE 34.—*Prospecting Licenses and Mining Leases granted in the Punjab during 1917.*

District	1917. No.	1917. Area in acres.	1917. Mineral
Prospecting Licenses.			
Attock	1	1,280	Mineral oil.
Shahpur	1	4,992	Do.
TOTAL	2		

THE SUPPORT OF THE MOUNTAINS OF CENTRAL ASIA (BEING AN APPENDIX TO THE MEMOIR ON THE STRUCTURE OF THE HIMALAYAS, AND OF THE GANGETIC PLAIN, AS ELUCIDATED BY GEODETIC OBSERVATIONS IN INDIA). BY R. D. OLDHAM, F.R.S. (With Plate 3).

IN the memoir on "The Structure of the Himalayas and of the Gangetic Plain, as elucidated by Geodetic Observations in India,"[1] it was shown that the outer zone of the hills was a region of partial defect of compensation, or, in other words, of super-elevation of the surface, which increased in amount from the outer edge of the hills to as far in as definite observations have been made. This being only about 40 miles, the ultimate course of the discrepancy between topography and compensation cannot be traced, but less certain observations, and other considerations, indicate that the defect of compensation disappears at greater distances from the edge of the hills and may even be replaced by an excess. The conclusion, being an important one in view of its bearing on theories of the origin of mountains, requires confirmation and, in the absence of observations in the Himalayan region, this had to be looked for elsewhere. In the search for such information I came across a series of gravity measurements, made by the Russian Government, in the region of the Pamirs and neighbouring parts of Central Asia, which are of special interest as giving a complete section across a group of mountains not only comparable in elevation with the Himalayas but also, in other ways, of importance in the discussion of theories of mountain origin.

The geology of this region is still imperfectly known, but this is of no very great importance as the present investigation is not concerned with details of stratigraphy. Enough is known to show that the general strike of the strata, and of the axes of the folds, is about east and west right across the northern part of the district. In the southern part, the same strike is found towards the centre, but on the east it bends round to south-eastwards, and westwards

[1] *Mem., Geol. Surv. Ind.*, XLII, pt. 2, 1917.

to the south-west. The topography shows a general agreement with the geological structure; on the north the upper waters of the Sir Daria, or Jaxartes, flow through the valley plain of Fergana, in what is evidently a structural depression between the mountains to the north and south. South of the Fergana valley come the parallel ranges of the Alai and Trans-Alai, separated by the Alai plain, near the head of the valley of the Kizil Su. These ranges are continued, further west, by others named on maps as the Peter the Great, Hissar, and Zerafshan, which together with the Alai ranges, may be regarded as the westerly continuation and termination of the Tian Shan mountains, now separated by the erosion of valleys, cut more or less along the strike of the rocks. To the south of these high ranges a number of minor ridges stretch in a more or less south-westerly direction towards the valley of the Oxus, following, in a general way, the strike of the rocks. The valley of the Oxus, or Amu Daria, occupies a structural depression to the westwards of the junction of the Kunduz river, but the upper reaches occupy what has all the characters of a valley of erosion, cut through the mountains, at times along, and at others across, the strike. Further still to the south comes the range of the Hindu Kush and its western continuation.

Throughout this region there is, as has been indicated, a general agreement between the geological structure of the rocks exposed at the surface and the geographical aspect of the country, but upon this general agreement of what may be called the minor topography, the course of crest and valley, there is superimposed a major relief, which is quite independent of the structure of the surface rocks and arranged along an axis transverse to the strike. This is very well seen in the hills of the drainage area of the Amu Daria, where we have the lowlands of Bokhara, on the west, eastwards comes a series of low hills which do not rise above 5,000 feet, followed by the high plateau of the Pamirs, and, still further east, by the mountains of Kungur and Mustagh Ata, which rise to heights of over 25,000 feet and form the highest summits of the region. The same feature may be recognised in the increase in average height from east to west of the series of ranges which form the backbone of the region and is also, and perhaps most conspicuously, marked by the feature known to geographers as the Mustagh Ata range, which lies outside the region covered by the gravity observations, but must be considered, as it will be shown to have an import-

ant bearing on the interpretation of them, and as its character is generally misunderstood.

Maps show a series of high mountains ranged along the border of the plains of Kashgaria, which are separated from the Pamir plateau by deep valleys, and are so conspicuously arranged along a nearly meridional line that, in spite of the interruption by two deeply cut valleys, it is natural to look upon them as forming a distinct and definite mountain range, which is variously designated as the Kashgar, Tagharma, or Mustagh Ata, range; the appearance is, in fact, so striking that it has even misled some geologists into regarding it as a true tectonic range, and accepting a system of disturbance of the strata which would cut right across the trend of the structure of the region immediately to the west, and of which no trace can be found in observation in the field. The Mustagh Ata and Kungur are composed of granite, and doubtless owe their preservation as the highest summits of the region to this, but to the north Dr. H. H. Hayden found that an easterly strike continued right across the line of the supposed range, up to the margin of the Kashgar plain,[1] and to the south Dr. F. Stoliczka found a south-easterly strike continued, with only a brief local occurrence of northerly strike from the edge of the plain till it bent round into the east-south-easterly strike of the Pamirs.[2] The similitude to a mountain range is largely due to the valleys which separate the summits from the Pamir plateau, and even if these valleys are not wholly due to erosion, there remains the fact that the greatest actual elevations lie in the extreme east of the region, and the common geographical interpretation has this much genetic justification, that the axis of the greatest uplift lies on the eastern edge of the hills, whence there is a rapid descent to the plains of Kashgar.

The major relief of the country is thus seen to cut right across the minor relief, or course of ridge and valley, and for this no satisfactory explanation can be found in the visible geological structure of the country. The structure very clearly indicates that the region has undergone compression in a north and south direction, and this compression would give rise to a thickening of the crust, to which the elevation of the hills might, and very commonly is, attributed; but there is nothing in our limited knowledge of this region to suggest that the compression has been greater in the east than in the

[1] *Rec., Geol. Surv. Ind.,* XLV, 318 (1916).
[2] Scientific Results of the Second Yarkand Mission Geology, pp. 35-37 (1878)

western portion, at any rate to the extent necessary to account for the difference in the present elevation of the ground. This, however, is merely a repetition of what may be found in other parts of the world. Even in those districts where the relation between inward structure and outward form are most intimate and obvious, there is not the same apparent connection between structure and absolute elevation. The Alps and the Himalayas, for instance, have both been compressed in a direction transverse to the general course of the range, and the amount of compression seems to be of much the same order of magnitude in both cases; the geology of the Himalayas is less fully known than that of the Alps, but so far as our knowledge goes the compression seems to have been, if anything, less in amount, and certainly there is nothing like the twofold greater compression, which would be needed to account in this way for the twofold greater elevation. In both these cases, as in others of a similar character, the major relief is ranged along much the same general direction as the minor, so that it is difficult to disentangle the effects of the two and decide how far each may or may not be determined by the geological structure. In the mountains of Turkestan the opposite is the case, and here the major and the minor relief are arranged along different lines, which cross each other nearly at right angles, and, for this reason, the region seems particularly favourable for the study of those problems of mountain formation, the solution of which seems impossible by geological observation and only to be approached by the study of geodetic measurements.

The results of the observations are published in the report of the 1909 meeting of the International Geodetic Association, but in less detailed form than is customary, for only the free air correction is given. The Bouguer correction for visible mass and the Hayford correction for local topography are easily obtained, but the orographic correction for departure of the actual surface from a plateau could not be determined with accuracy from the maps accessible to me. As the stations are mostly situated in open valleys or out in the plain, this correction will in the majority of cases be less than ·01 dyne and only in a few cases, where the station is situated in a deep and narrow valley, will it exceed ·02 dyne, and is not likely to be greater than ·03 at any station of the series.

The correction for the effect of topography at a greater distance than 104 miles from the station has been determined. It was computed in detail by Messrs. Hayford and Bowie for the station of Kala Khum,[1] which is almost centrally situated in the group of stations being dealt with, and, as the amount of this correction varies comparatively slowly from station to station, the adoption of the same value at all would probably not introduce an error of more than ·02 dyne at any one. Moreover, the error would be a systematic one, changing gradually from one margin of the map towards the other, and so easily recognisable, if not obscured by other and greater irregularities. As will be seen in the sequel, the differences in the anomalies are much greater in amount and more rapid in their variation than can possibly be accounted for by the neglect of this correction. Another consideration is the fact that the correctness of the adopted value for the force of gravity at Tashkent, on which all the other values depend, is in doubt,[2] and for this reason it has seemed best to confine attention to the differences, which are most conveniently expressed as positive or negative variations from the mean value of the whole group, excluding the anomalous station of Kala Wamar. The stations are numerous enough, and the area sufficiently extensive and diversified in character, to make it probable that the mean of the anomalies will approximately represent the true zero value for the area, while the exclusion of Kala Wamar is justified by the anomalous character of the record. The negative anomaly at this station is not only abnormally high, but is nearly two-tenths of a dyne higher than at the nearest stations. There is no apparent explanation of so great an anomaly at this station, and it is difficult to avoid the conclusion that a clerical error has crept into either the calculations or their transcription, the alternative explanation being that there is some exceptional and quite local peculiarity at this station; in either case its exclusion is justified.

On the map attached to this note (Pl. 3) the relief of the surface is indicated by the contours at intervals of 5,000 feet and the positions

[1] The effect of Topography and Isostatic compensation upon the Intensity of gravity. Washington; 1912; p 84.

[2] Comptes Rendues de la seizieme Conference générale de l'Association Geodesique Internationale, Vol. III, pp. 138-141.

of the gravity stations, with the amount, expressed in hundredths of a dyne, by which the anomaly differs from the mean value. As has been mentioned, these values require a correction for irregularity of the surface, which may reach ·03 dyne and will be less at most of the stations in the mountain region; they are also subject to a correction on account of distant topography and its compensation, which will vary gradually from a positive value near one margin to a negative value at the other, or possibly may vary in either positive or negative direction from some point within the area. Another possible correction is a divergence of the actual distribution of the compensation from that assumed in the Hayford and Bowie tables, from which the figures made use of were derived; any such assumption, however, not inadmissible on other grounds, would make very small change in the amount of the anomaly, the maximum change, at the stations in the very heart of the mountains, could not exceed ·02 dyne at any individual station and would vary in amount with the altitude.

An inspection of the map shows that the actual variation in the amount of the anomaly is not susceptible of explanation in any of these ways; not only is the amount of the difference too large, reaching as it does about two-tenths of a dyne, but the distribution shows no relation to the situation of the stations, whether in deep and narrow valleys or in the open plain, nor to the elevation, nor does it vary in a manner that could be attributed to the effect of distant topography. On the other hand, the variation does show a very decided relation to the general relief of the country; in the lowlands to the west we find the anomalies all positive, and the positive values continue into the hills on the east; as the higher hills are entered the anomalies become negative, and all the eastern stations show a negative anomaly, with the exception of two groups, one in the central region of the Pamir plateau, and the other in the depression of Fergana. Expressed in general terms, it may be said that the character of the anomaly is such that where lower ground borders on higher the anomaly is positive, and negative where high ground is bordered by lower. In the case of the western plains of Bokhara, and again in the Fergana depression this relationship is obvious. but not so on the Pamir plateau, yet there, too, high as the stations lie, there is higher ground on all sides, though the barrier on the west is breached by river valleys. The station of Jekindi, which shows a small positive anomaly, isolated in a region of defect of gravity, is no exception

for, though situated in a mountain region, it lies in the upper valley of the Kizil Su and not very far from the edge of the Alai plain, which, lying between the Alai and Trans Alai ranges, appears to mark a structural depression between two lines of excess of uplift.

Bearing in mind the fact that a positive anomaly, where the effect of compensation has been considered, means that the surface level stands higher than it would if a condition of complete isostatic equilibrium existed under the station, the distribution of the anomalies may be expressed in a different way, as indicating that the low ground is borne up above, and the ranges depressed below, their respective proper levels. This is the condition which was established as regards one part, and shown to be probable as regards the other, in the case of the Himalayas, and, in that connection, was shown to suggest a certain amount of residual rigidity in the crust of the earth. The way in which this would work can be illustrated by the diagram, fig. 1, where an originally level surface is supposed to have been subjected to elevatory forces such as would result in a surface as represented by the firm line between A and H, if the surface level everywhere coincided with the upward or downward forces; if, however, the crust were possessed of a degree of permanent rigidity which would not allow it to adapt itself to the flexures, the resulting surface would take some such form as that represented by the dotted line, the exact form depending on the degree of rigidity of the crust and the abruptness of the flexures.

Fig. 1.

Here we see that on either side of the central uplifted tract, the level surface is bent upwards and stands at a higher level than it otherwise would, while the outer edges of the uplift are held down below the level which they should have reached. In the centre of the plateau it might be that the surface would be forced up above its proper level by an arching upwards of the crust, as a result of the bending down on either side.

The conditions assumed in the diagram have been reduced to an extreme simplicity, but a similar result would follow in more

complicated circumstances, and, further, if we suppose the elevatory force to be the result of the same changes which have given rise to the compensation, we should find an apparent excess of gravity in all those regions where the dotted line runs above the firm one, and where the actual amount of the compensation would be less than that deduced from the measured altitude; where the dotted line runs below the firm there would, similarly, be an apparent defect of gravity, the real compensation being greater in amount than was allowed for in the computation.

Before passing on to the consideration of the observations it may be well to point out that if the compensation were an indirect result of the accumulation of surface material to form the plateau, the relationship between the real surface and the surface of equilibrium would be the opposite of that shown in the diagram. In this case the ground on either side of the plateau would be borne down, and a defect of gravity would be observed, while the plateau would be supported above the level of equilibrium and show an excess of gravity.

Examining the anomalies in the light of this explanation, we find, in the first place, high positive values in the most westerly stations; then, entering the hills, this positive anomaly decreases in amount in an easterly direction, as the high plateau of the Pamirs is approached, till it disappears and is replaced by a negative anomaly both in the stations along the course of the Oxus and in the hills to the north of it.

In the upper Oxus valley, the anomaly has a negative value of about ·06 dyne at Kala Khum, of which ·01 is due to the omission of the orographic correction. At Kala Wanj, Kharuk and Ishkasham the negative anomaly amounts to ·08, of which some ·02 to ·03 may be due to the orographic correction, and at Langar Kisht, where this correction is probably larger than at any other station, the negative anomaly of ·11 would be reduced to ·07 or ·08.

Eastwards of these high negative values there are no stations till the Pamir plateau is reached, where a group of positive anomalies is met with, the greatest of which amounts to ·11 dyne, at Robat Muskol. This very high value may be attributable, in part, to a purely local variation in the density of the rocks under the station, and it may be that the lesser positive anomalies at the neighbouring

stations would be made negative by a computation including the effect of more distant topography, but any such change would still leave the values positive in comparison with the anomalies at the stations round about.

Taking an anomaly of ·03 dyne as representing in round numbers the attraction of 1,000 feet thickness of average rock, we may interpret the figures as showing a superelevation of about 3,000 feet in the plain about Bokhara, a depression of rather less along the edge of the high plateau of the Pamirs, about Kala Khum or Kala Wanj, and a superelevation of about the same amount in the central part of the plateau round about Robat Muskol. The distance from Charjui to Robat Muskol is about 550 miles and the maximum difference of load equivalent to about 5,000 feet of rock, indicating a permanent strength of the crust of more than double that which, according to Prof. Barrell, is revealed by the observations in the United States, but only about one-half to three-quarters of that exhibited by part of the floor of the Pacific Ocean.[1]

On this line of section, a disturbing element may come in, of the effect of which we can form no estimate, for the line is flanked on the north by the high ranges stretching westwards between the Oxus and Jaxartes valleys, and on the south by the Hindu Kush and its westerly continuation. Nothing of the same proportionate amount needs consideration on the transverse section from north to south across the Pamirs. Beginning from the south, we find a negative anomaly at Langar Kisht which, allowing for the effect of the orographic correction, is equivalent to a depression of about 3,000 feet. This station is close to the crest of the Hindu Kush and to peaks which rise to an altitude of 22,000 to 24,000 feet. At Murghabi, the depression has sunk to −·04 dyne and, as the orographic correction would be comparatively small, the depression may be put at about 1,000 feet. At the next station, Robat Ak Baital, there is a superelevation of about the same amount, which increases to 3,000 feet or more at Robat Muskol. Lake Karakul seems to stand at about the level due to the compensation but northwards the depression at Bordaba amounts to 1,000 feet and to 3,000 feet at Ak Bossaga, diminishing again to about 1,000 feet at Sufi Kurgan and Gulcha. At Liansar and Osh, in the Fergana valley, there is a positive anomaly, indicating a superelevation of

[1] *Journ. Geol.*, XXII, 30, 37, 38 (1918).

less than 1,000 feet, surrounded on three sides by stations indicating a depression of the surface level, as the mountains are neared.

On this section the bearing up of the low ground, and the bearing down of the high, is very clearly exhibited. In the case of the Fergana valley it is obvious enough, and, as has been pointed out, the central region of the Pamir plateau is in much the same case, in spite of its altitude, but here another cause may co-operate in producing superelevation. The observations indicate a bending down of the crust towards the north and south, and towards the west; on the east no observations exist but we may infer that a similar condition would be found towards the plains of Kashgar.

Granted the correctness of this interpretation, the strength and rigidity of the crust implied by it might well give rise to an upward bending of the portion of the crust lying between and so to an uplift, reaching its maximum in the centre and dying out on either side, as was suggested in dealing with the suppositious case illustrated in fig. 1.

However this may be, we have a section which may be regarded as something over a complete wave, having a length of about 150 miles from crest to crest or trough to trough, and a height of about 7,000 feet from trough to crest. This last figure may be excessive, and partly due to this increase of the maximum anomalies by purely local causes, but the general average of the observations shows that the difference is at least equivalent to some 5,000 feet or 2,500 above and below the mean level of equilibrium.

Westwards from Fergana the stations in the drainage area of the Sir Daria, or Jaxartes, show the same features, of negative anomalies on the east giving place to positive anomalies to the westwards, as was found further south. It is not possible to recognise any influence of the high mountains which lie between the two rivers, as there are no stations within the ranges or close to them, and the elevated mass is so insignificant in volume, as compared with the Pamir plateau, that the effect of the latter would be predominant, and any influence exerted by the former only recognisable by a larger number of more closely set stations than are available.

Taken as a whole, the results agree in a remarkable manner with those obtained from the study of the geodetic observations in the Himalayas, indicating that a condition of general isostatic equilibrium, of the mountains as a whole, is subject to considerable

local departures from this condition. In both cases these departures from complete equilibrium are distributed with a marked relation to the greater relief of the surface and are just such as would result from the uplift being due to some deep-seated cause, acting mainly in a vertical direction, combined with some considerable strength and permanent rigidity of the overlying crust, which is, consequently, prevented from adapting itself completely to the bending, and so may hold the surface level down below or upraised above that at which it would otherwise stand. The limit to the amount of the departure from the level of equilibrium is about the same in both regions and reaches a maximum of some 3,000 feet; the observations which have been made in the Andes suggest a similar departure from complete equilibrium and to about the same amount. We find, then, that three great mountain ranges, each of about the same magnitude, and the three greatest in the world, agree in showing the same phenomenon and to the same degree. This would in itself give great support to the supposition that there is a real connection and a cause common to all. There are, besides, within the limits of the region now under consideration, two groups of facts, wholly independent of each other, and each in its way giving support to the deduction that the greater relief of the surface is independent of the superficial geological structure, but is directly due to the same processes as have given rise to the compensation.

The first of these is the fact that the course and distribution of the principal mountain ranges and the larger features of the relief of the ground are not directly determined by the geological structure. The point is very clearly brought out in a paper by Dr. Ellsworth Huntington, on the Mountains of Turkestan, and can hardly be more graphically and succinctly expressed than by three brief extracts from his account, in which he consistently writes of the Tian Shan Mountains as a plateau and never as a range.[1]

"In physiographic terms, the Tian Shan plateau may be described as a peneplain which has been highly uplifted and warped, and is now in a state of extreme youth". * * * "The result of these geological changes is that, although the *internal structure* of the Tian Shan region is highly mountainous, its *external appearance*, or, in other words, its geographical aspect, is that of a plateau" * * * "The ridges rise by long gentle slopes to flat summits,

[1] *Geog. Journ.*, XXV, pp. 22-40, 139-158 (1905).

where often for many miles the sky-line is an almost straight crest from which the rounded slopes of pure white snowfields descend gradually toward the basins. Here and there the crest line is notched by high passes, the lowest of which are but 1,000 or 2,000 feet below the top of the ridge. Oftener the summit of the ridge is broken into individual mountains, broadly flat topped and of nearly equal height."

The description of this author is borne out by that of every other traveller, and the region appears as one which has undergone a very considerable amount of disturbance, accompanied by a general compression of the strata, which may have given rise to true tectonic irregularities in the form of the surface. These original features had been worn down and the country reduced to a lowland type of gentle relief, such as it is the fashion to describe as a peneplain, when, at a later date, the country was uplifted and, by the opportunity so given to the action of denudation, the surface carved into steep slopes, and deep-cut valleys, converting a downland plateau into the aspect of a series of mountain ranges. The uplift was not uniform, but greater along certain lines than elsewhere, and in some cases these lines of greater elevation followed the general course of the earlier axes of disturbance of the strata, so that the present range of high crests has the appearance of being a true tectonic range, but even in these cases the amount of the later elevation varies along the length of the range, and the variation has no relation to the geological structure. More generally, however, there seems no direct connection, and the most conspicuous geographical feature of the region, the line of mountains running north and south, between the Pamirs and the Plains of Yarkand and Kashgar, runs right across the trend of the geological structure. This series of mountains is so distinctly ranged along a definite axis that it may naturally be regarded as a definite range, and the study of the topographical map has even led geologists to infer the existence of a meridional range of true tectonic character. As has already been mentioned, the surface observations are opposed to this conclusion, and show that, if the range is in any sense of the word a tectonic one the tectonics are more deeply seated than those of the disturbance of the rocks near the surface.

The consideration of this range, which is seen to be probably a true range, genetically as well as in superficial appearance, merely emphasises the conclusion drawn from the general study of the region,

that the broad features of the major relief, as well as the determination of the more restricted zones of greater uplift, are not the result of processes apparent in the structures visible at the surface, but of more deeply seated, and possibly quite independent, processes, which are not accessible to surface observations, and are, presumably, connected with the cause of compensation.

The second group of facts has a more direct bearing on the particular nature of the changes, or processes, which produce the compensation. It is known that great earthquakes send out two sets of waves, which are transmitted through the interior of the earth and recorded at distant stations. In addition to the record of the waves which have travelled by direct courses, there are subsidiary records which are attributed to those which have been one or more times reflected; though the interpretation of the records has been questioned, and is certainly doubtful as to some of the supposed twice or more times reflected waves, the concordance of a very large proportion of the records seems to have established the presence of the two types of singly reflected waves, the condensational and the distortional, each reflected from a midway point as the same form of wave. In the mathematical treatment of this question it is usual to assume a reflection from the surface of a solid sphere, and this is too often taken to mean that it takes place at the surface of the earth; this, however, is impossible, in the case of the actual records, for the rocks of which the outer shell of the earth is composed are too heterogeneous to transmit a simple form of wave-motion without repeated breaking up into waves of more than one form, and the constituent rocks have, almost without exception, so different a degree of elasticity in different directions that they are incapable of transmitting either of the simple forms of wave-motion. The result is, that the simple waves, on entering the outer crust, become broken up into more complex forms and lost; consequently, it is not at the surface of the earth that we must look for the surface of reflection, but at the under surface of the heterogeneous crust, and it is reasonable to find an explanation, of the greater or less conspicuousness of the record of the reflected waves, in the varying degree of abruptness of transition to the more uniform material below. Now it has been observed that, of all the earthquakes registered at European observatories, those originating in the neighbourhood of the Philippines, that is, those which have the central point of reflection under the region of high

mountains of Kashmir and the Pamirs, give the most conspicuous record of the reflected waves, usually even larger than that of the distant ones.

The obvious interpretation of this is that the transition from the outer crust to the underlying material is more than usually rapid and sharply defined in the region under the Pamirs, and it is natural to associate this with the changes which have given rise to the compensation of this group of mountain ranges, the largest and loftiest in the world. And so we reach the same conclusion as was drawn from the gravity observations, that the processes and changes, to which the effect is due, are localised, or at least concentrated, in the lower part of the crust, or in the layer immediately beneath it.

The conclusion reached in the course of this investigation may not be without importance on the geodetic side, as a guide in the determination of the nature, and distribution in depth, of the compensation. On the geological side it is of great interest as showing that two distinct causes and actions have been at work and must be taken into account in any attempt to elucidate the origin of mountain ranges. On the one hand, we have the actions which have given rise to the disturbance of sedimentary rocks from their originally horizontal position, and to the intrusion of igneous rocks among them. The well-established importance of trend-lines of structure is unimpaired, and to the structure set up in this way, combined with the effects of surface denudation, the details of surface form and the course of ridge and valley are due. The boundary between hill and plain is often determined by the same cause, and to it ranges of hills may sometimes be due, but there is a distinct limit to the amount of the difference of elevation which can be produced in this way. No exact figure can be given for these limits; they are probably incapable of precise numerical definition, but the limit of height must be somewhere about 2,000, or possibly, 3,000 feet, and the limit of breadth 150 to 200 miles. Where the difference becomes greater than this, we must look to some other cause than compression of the rocks, for the load imposed on the crust becomes too great for it to bear, and so the conclusion is reached that the larger differences in elevation, and the more extensive areas of uplift, are due to some cause which is independent of that which has given rise to the structures revealed by the geological examination of surface rocks.

As a speculation this is not new, but the present investigation has given clearer indication of its truth than had previously been published, within my knowledge, and more especially has shown, in the first place, that the uplift of the higher mountain ranges is directly connected with those changes which have given rise to the defect of density under the ranges, known as their compensation, and, in the second place, that these changes are deep-seated and take place at the lower limit of the outer crust. Of the nature of these changes, or the way in which they are brought about, the investigation gives no direct indication, but, from the intimate connection between the uplift and the compensation, it follows that the centre of gravity of the two is probably at the same average depth, and this, according to Mr. Hayford's investigation, is somewhere about 35 miles below the surface. Further, the distribution of the departures from complete local equilibrium are such as to show that the compensation is not the indirect effect of the formation of the mountain ranges, but that it is the primary phenomenon and the originating cause of the uplift, of which the mountains are the indirect result and to which they owe their present altitude.

LIST OF STATIONS AND DETAILS OF OBSERVATIONS UTILISED.

[NOTE.—The Stations in this list belong to two series of observations, one based on Tashkent, the other on Tiflis. As the value adopted for the base station in the former differs from that determined for the same place in the latter, and earlier in point of date, by ·015 dyne, a correction of this amount has been made at the other stations in order to bring the two series into uniformity. Stations of the series based on Tiflis, to which the correction has been applied, are distinguished by an asterisk. Spelling of place names follows the Survey of India, or a similar system where the name is not to be found on published maps.]

Station.	Longitude.	Latitude.	Elevation (in metres).	Observed value of gravity.	Theoretical value of gravity.	Apparent amount of defect.	CORRECTIONS.			Resulting anomaly.	Difference from mean.
							Height.	Mass.	Compensation.		
1. Murghabi	73° 58·2′	38° 10·0′	3,700	978·832	980·004	1·172	1·142	·407	·320	—·117	—·04
2. Irkeshtam	55·5′	39° 41·9′	2,850	9·203	0·139	0·936	0·880	·313	·232	—·137	—·06
3. Robat-Ak-Baital	51·5′	38° 29·7′	4,100	8·842	0·033	1·191	1·265	·451	·326	—·051	+·03
4. Robat Muskol	31·7′	38° 42·0′	4,200	8·924	0·051	1·127	1·296	·462	·328	+·035	+·11
5. Lake Karakul	31·2′	39° 6·4′	3,920	8·912	0·087	1·175	1·210	·431	·315	—·081	·00
6. Sufi Kurgan	30·0′	40° 1·5′	2,115	9·424	0·168	0·744	0·653	·232	·210	—·113	—·03
7. Gulcha	25·7′	40° 19·0′	1,583	9·580	0·195	0·615	0·489	·174	·185	—·115	—·03
8. Bordaba	16·2′	39° 30·9′	3,470	9·028	0·122	1·094	1·071	·382	·293	—·112	—·03
9. Ak Bossaga	13·7′	39° 48·6′	2,875	9·134	0·149	1·015	0·887	·316	·259	—·185	—·10
10. Liansar	5·7′	40° 24·6′	1,685	9·615	0·202	0·587	0·520	·185	·174	—·078	·00
11. Osh	72° 46·6′	40° 31·4′	1,021	9·791	0·212	0·421	0·315	·112	·156	—·062	+·02
12. Langar Kisht	38·5′	37° 2·6′	2,915	8·847	979·906	1·059	0·900	·320	·289	—·190	—·11
13. Andijan	20·6′	40° 45·8′	530	9·885	980·234	0·349	0·164		·111	—·132	—·05
14. Karaul Kishlak	6·0′	40° 2·2′	1,300	9·611	0·169	0·558	0·401	·143	·166	—·134	—·05

15. Jekindi . .	71° 54·5′	39° 30·0′	2,380	9·321	0·121	0·800	0·734	·262	·260	—·068	+·01
16. Margilan . . .	46·7′	40° 23·7′	581	9·863	0·201	0·338	0·179	·064	·122	—·101	—·02
17. Namangan . .	38·7′	40° 59·7′	440	9·941	0·255	0·314	0·136	·048	·098	—·128	—·05
18. Kharuk . . .	32·2′	37° 29·5′	2,105	9·132	979·944	0·812	0·650	·231	·236	—·157	—·08
19. Kala Wamar . .	32·0′	37° 56·7′	1,985	9·019	9·984	0·965	0·615	·218	·230	—·340	—·26
20. Ishkasham . .	30·2′	36° 52·4′	2,460	8·967	9·981	0·924	0·759	·271	·277	—·159	—·08
21. Kala Wanj . .	27·0′	38° 22·2′	1,795	9·290	980·021	0·731	0·554	·197	·218	—·156	—·08
22. Dambarachi . .	22·7′	39° 16·1′	1,795	9·393	0·101	0·708	0·554	·197	·228	—·123	—·04
23. Chust . . .	13·9′	40° 59·3′	639	9·916	0·254	0·338	0·197	·070	·098	—·113	—·03
24. Khokand . .	70° 57·0′	40° 30·5′	437	9·913	0·211	0·298	0·135	·048	·089	—·122	—·04
25. Kala Chait . .	52·0′	39° 10·8′	1,600	979·443	0·093	0·650	0·494	·176	·209	—·123	—·04
26. Kala Khum . .	46·5′	38° 27·3′	1,345	9·462	0·029	0·567	0·415	·148	·165	—·135	—·06
27. Tabidarreh . .	28·2′	38° 41·9′	1,630	9·440	0·051	0·611	0·503	·179	·167	—·120	—·04
28. Garm . . .	22·2′	39° 1·5′	1,370	9·498	0·079	0·581	0·423	·151	·189	—·120	—·04
29. Jol	7·7′	37° 45·8′	1,380	9·437	979·968	0·531	0·426	·152	·127	—·130	—·05
30. Saripul . . .	5·5′	38° 24·5′	1,500	9·462	980·025	0·563	0·463	·165	·150	—·115	—·04
31. Muminabad . .	1·7′	38° 6·5′	1,280	9·491	979·999	0·508	0·395	·141	·130	—·124	—·04
32. Bogarak . . .	69° 50·2′	37° 37·0′	610	9·609	9·956	0·347	0·188	·067	·160	—·120	—·04
33. Baljuan . . .	39·2′	38° 18·2′	890	9·591	0·015	0·424	0·275	·098	·113	—·134	—·05

Station.	Longitude.	Latitude.	Elevation (in metres).	Observed value of gravity.	Theoretical value of gravity.	Apparent amount of defect.	CORRECTIONS. Height.	Mass.	Compensation.	Resulting anomaly.	Difference from mean.
34. Khodjend . . .	34·7′	40° 17·1′	320	9·953	0·192	0·239	0·099	·035	·076	—·099	—·02
35. Parkhar . . .	23·7′	37° 29·9′	475	9·659	9·945	0·286	0·147	·052	·078	—·113	—·03
36. Nau . . .	22·4′	40° 9·2′	415	9·951	0·180	0·229	0·128	·045	·074	—·072	+·01
37. Faizabad . .	18·7′	38° 30·9′	1,210	9·581	0·034	0·453	0·373	·133	·122	—·091	—·01
38. Sarai . . .	5·0′	37° 13·9′	405	9·661	979·922	0·261	0·125	·045	·061	—·120	—·03
39. Ura Tyube . .	0·7′	39° 55·3′	1,025	9·814	980·159	0·345	0·316	·113	·095	—·047	+·03
40. Dushambe . .	68° 46·7′	38° 34·5′	835	9·673	0·040	0·367	0·258	·092	·109	—·092	—·01
41. Chernajajewo . .	43·6′	40° 13·0′	360	980·003	0·186	0·183	0·111	·040	·065	—·047	+·03
42. Nishne Panj . .	31·7′	37° 11·5′	355	979·699	779·918	0·219	0·110	·039	·051	—·097	—·02
43. Zamin . . .	23·5′	39° 58·2′	650	9·896	980·163	0·267	0·201	·071	·074	—·063	+·02
44. Karatagh . .	20·0′	38° 36·7′	905	9·684	0·043	0·359	0·279	·099	·114	—·065	+·02
45. Aivanj . . .	1·7′	36° 56·9′	340	9·693	979·897	0·204	0·105	·037	·052	—·084	00
46. Deh Nau . . .	67° 53·7′	38° 16·3′	550	9·751	980·013	0·262	0·170	·060	·089	—·063	+·02
47. Jisak* . . .	48·7′	40° 6·8′	386	980·018	0·176	0·158	0 119	·043	·052	—·030	+·05

48. Panjikand . .	36·2′	39° 29·8′	980	997·768	0·121	0·353	0·302	·108	·108	—·051	+·03
49. Sangardak . .	33·0′	38° 32·8′	1,330	9·600	0·037	0·437	0·410	·146	·115	—·058	+·02
50. Urgut . . .	15·2′	39° 24·6′	995	9·755	0·113	0·358	0·307	·109	·095	—·065	—·02
51. Termez . . .	13·6′	37° 13·7′	346	9·711	979·922	0·211	0·107	0·38	·041	—·101	—·02
52. Baisun . . .	12·5′	38° 12·0′	1,230	9·624	980·007	0·383	0·380	·135	·096	—·042	+·04
53. Derbent* . .	3·2′	38° 12·0′	1,012	9·687	0·007	0·320	0·312	·111	·089	—·030	+·05
54. Shirabad* . .	2·6′	37° 40·9′	479	9·756	979·961	0·205	0·148	·053	·063	—·047	+·03
55. Samarkand* . .	66° 58·7′	39° 39·1′	719	9·898	980·135	0·237	0·222	·079	·074	—·020	+·06
56. Yaka Bagh . .	52·0′	38° 55·4′	700	9·802	0·070	0·268	0·216	·077	·092	—·037	+·04
57. Sharshauz* . .	50·2′	39° 3·4′	646	9·907	0·082	0·175	0·199	·071	·086	+·039	+·12
58. Guzar* . . .	17·0′	38° 36·6′	555	9·861	0·043	0·182	0·171	·061	·071	—·001	+·08
59. Kilif* . . .	15·7′	37° 20·7′	290	9·821	979·932	0·111	0·089	0·32	·038	—·016	+·06
60. Katta Kurgan* .	15·5′	39° 54·2′	477	9·994	980·157	0·163	0·147	·053	·041	—·028	+·05
61. Kermine* . .	65° 23·1′	40° 4·4′	398	980·038	0·173	0·135	0·123	·044	·030	—·026	+·05
62. Kerki* . . .	13·8′	37° 50·1′	262	979·884	979·974	0·090	0·081	·020	·019	—·019	+·06
63. Bokhara* . .	64° 34·7′	39° 43·0′	225	980·091	980·141	0·050	0·069	0·25	·017	—·011	+·09
64. Karakul . . .	63° 52·7′	39° 29·9′	198	0·062	0·121	0·059	0·061	·022	·015	—·005	+·08
65. Charjui* . .	36·1′	39° 6·2′	192	0·029	0·086	0·057	0·059	·021	·015	—·004	+·08
66. Repetek* . .	14·1′	38° 33·7′	188	979·946	0·039	0·093	0·058	·021	·015	—·041	+·04

NANABHAI DAYABHAI DARU.

IT is with much regret that I have to record the death on September 26th of Mr. N. D. Daru, Assistant Superintendent in this Department. Mr. Daru, after training in England and Canada, joined the Geological Survey of India on December 4th, 1907, and was employed at first in reporting on the alum industry in the Salt Range. He was subsequently attached to the Central India and Rajputana party, and carried out the revision of the geological map of Dungarpur State. His natural bent, however, led him rather to the educational side of his subject, and he occupied the post of Lecturer on Geology at the Poona Engineering College for three years and of Professor of Geology at the Presidency College, Madras, for two years. Soon after his resumption of field-work in 1916 his health gave way; he returned from leave on medical certificate only in April last, but was again compelled to take similar leave almost immediately. His early death is sincerely regretted by all his colleagues.

H. H. HAYDEN.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1918. [December.

NOTES ON STRUCTURE AND STRATIGRAPHY IN THE NORTH-WEST PUNJAB. BY E. S. PINFOLD, B.A., F.G.S., STUD.INST.M.M. (With Plates 4 and 5).

THE search for oil in the Attock and Rawalpindi districts has necessitated a detailed investigation of the Tertiary succession in this part of India. The older classification has been considerably enlarged and the correlation of the local stratigraphy with that of the adjoining regions has shewn that current nomenclature needs revision. Such must be my excuse for publishing these incomplete notes.

Prospecting work is necessarily of a different character from those detailed studies which usually form the subjects of geological papers. The prospector's maps are sufficient only for economic purposes and his attention is confined to those problems which have a direct bearing on the mineral resources of the region examined; the purely academic aspects of the geology must be subsidiary to his economic work.

In the Punjab the rock groups are so easily distinguished by their lithological characters that their palæontology is of only secondary importance and has had to be almost entirely neglected. Such an omission, however, is of less importance than may seem at first sight, for the stages into which the Tertiary rocks of the Punjab have been divided were deposited each under such different conditions and are so constant in lithology that later palæontological research can only confirm the classification based on strati-

graphic characters. On the other hand, palæontology must be the deciding factor in any correlation of the Punjab succession with that of distant regions and the suggestions put forward in this paper must await the further description of the fossils before they can be accepted as definitely proven.

PREVIOUS WORK.

Wynne.

The geological survey of this part of the Punjab and the adjoining portions of the Northwest Frontier Province was carried out by Wynne.[1] The small scale geological maps published with his papers cover the whole area and are continuous with Medlicott's map of Jammu on the same scale.[2] I am glad of this opportunity to acknowledge the great assistance which Wynne's work has been to us in guiding our prospecting in north-western India. His maps give the main outlines of both stratigraphy and structure and have been found to be remarkably accurate considering the large area which he covered and the many disadvantages under which he worked. Wynne's survey affords a good example of thorough work which seemed at that time to be of purely scientific interest but which, with the advance of our knowledge, is now of great importance in the economic development of the region.

Wynne shewed that all the rock groups previously distinguished in the Simla region were represented in the Punjab succession. He divided the upper Tertiary fresh-water series into two systems, the Siwalik and the Murree, the latter corresponding to the Dagshai and possibly also to the Kasauli beds of the Simla succession. Wynne subdivided the lower Tertiary limestones into an upper series of limestones and shales, which he correlated with the Subathu stage, and a lower series of massive limestones, generally referred to as the "hill limestones," which apparently are not represented in the Simla hills.

Wynne claimed that there was a gradual passage from the massive limestones through the Subathu beds into the fresh-water Murree sandstones and shales. In this Wynne was certainly in error and it is the persistence of Wynne's ideas of passage from

[1] *Rec. Geol. Sur. Ind.*, Vol. X, p. 107, (1877); *ibid*, Vol. XII, p. 100, (1879).
[2] *Rec. Geol. Sur. Ind.*, Vol. IX, p. 49, (1876).

one series to the other which is chiefly responsible for the confusion of nomenclature in recent papers.

Middlemiss: Hazara.

The Hazara hills, which adjoin Wynne's Punjab work on the north and east, were partly mapped by Wynne and the survey was completed by Mr. Middlemiss.[1]

Two representatives of the Punjab succession, the hill limestones and the Murree sandstones and shales, are present, but the intervening Subathu series was not recognised. A group of shales—the Kuldana series—between the limestones and the Murrees was separately mapped and occupies a corresponding position to that of the Subathu beds in the adjoining regions; these Kuldana beds were regarded as passage beds between the marine limestones and the fresh-water sandstones and shales of the Murree system.

Pilgrim.

Dr. Pilgrim has confined his attention to the upper Tertiary fresh-water series, the Murree and Siwalik, and it is due entirely to his work on the vertebrate fossils of these formations that we can now recognise a definite succession in an otherwise monotonous section of vast thickness.

Wynne's belief in a gradual passage from the limestones to the fresh-water sandstones and shales had been questioned by his contemporaries.[2] Dr. Pilgrim was the first to bring forward decisive evidence on this point; he shewed that the vertebrate fossils in the basal bed of the Murree series were not older than the Gaj whereas the fauna of the underlying marine beds was of Khirthar age.[3] He thus proved a time gap equivalent at least to the whole of the Nari. The basal bed of the Murree series contains locally abundant nummulites and this fact formed one of Wynne's main arguments in support of his supposed passage. Dr. Pilgrim shewed that these nummulites were derived and must therefore be regarded as evidence for rather than against unconformity.

Dr. Pilgrim has now recognised seven distinct horizons, including the basal Murree bone-bed, each characterised by a distinct fauna, and has been able to correlate these with similar zones in Sind and Baluchistan in the west and Jammu and the Siwalik hills in the east.

[1] *Mem. Geol. Sur. Ind.*, Vol. XXVI, (1896).
[2] Manual of the Geology of India, 2nd Edn., p. 355.
[3] *Rec. Geol. Sur. Ind.*, Vol. XL, p. 188, (1910); *ibid*, Vol. XLIII, p. 264.

STRUCTURE.

Northern limestone ranges.

The northern boundary of the region described in these notes is the Kala Chitta range which crosses the Attock and Rawalpindi districts in an east and west direction from the Indus to near Golra. This range is formed by massive limestones—principally the hill limestones—intensely contorted by compression. The limestones have been thrust southwards over the Murree rocks of the foot-hills. Eastwards, near Golra, the Kala Chitta range sinks to the general level of the foot-hills, becomes much simpler in structure and eventually tails off in a narrow anticline of Subathu beds flanked by the Murree series at the same topographic level.

At the eastern end of the Kala Chitta range, about five miles further north, another limestone anticlinal rises *en échelon* eastwards to form the Margala hills. This range also is overthrust to the south and Mr. Middlemiss regards this thrust-plane as the structural equivalent of the boundary fault in the outer Himalayan foot-hills further east.

South and east of the Kala Chitta range and parallel with it is a long narrow limestone inlier, the Khaire Murat ridge. This, like the more important northern ranges is over-thrust southwards but the structure is otherwise much simpler and in the section on the north side of the ridge the limestones are overlain normally by Subathu and Murree beds.

The strike is east and west in the Attock district but in Rawalpindi the fold axes swing northwards into the western flank of the Tret-Murree synclinal.

Isoclinal region.

The foot-hills of the limestone ranges are formed by Murree rocks folded isoclinally and dipping steeply northwards. The remnants of anticlinal crests are to be seen in places but more commonly the only traces of anticlinal structure are long narrow outcrops of the upper limestone groups. In the west, towards the Indus, the compression has been less severe and the synclines are open folds sometimes of considerable extent. In this region there is no marked difference between the isoclinal zone and that next to be described.

Fault zone.

The isoclinal belt is about twenty miles wide. It is bounded on the south by a strike-fault which crosses the Indus west of Jand and can be traced continuously eastwards through Mianwali village to south of the Khaire Murat ridge, a distance of over forty miles. South of this

fault the structure is more open and can be completely elucidated. For about ten miles across the strike the anticlines are all closely folded and most of them are replaced by strike-faults similar in character to the Mianwali fault. The general structure in this zone is a series of open synclinal basins separated from each other by saddles and bounded to the north and south by strike-faults. Four of these faults, including the Mianwali fault, have been mapped. All of them extend westwards to the Indus. The Mianwali fault extends furthest to the east and the faults diminish in length southwards. The most southerly fault occurs near Chhab and can be traced eastwards from the Indus for over fifteen miles. This fault has all the characters of an ordinary overthrust and the anticline to the north of it is the only major anticline which can be recognised in this fault belt. It is closely compressed and a crest can only be distinguished at the eastern end of the fold. The other anticlines are the saddles between the basins and these pitch sharply from the point at which they are truncated by the strike-faults towards the synclinal axes. Such are the Meyal, Gulial and Uchhri folds.

Anticlinal zone.

South of the Chhab fault there is a zone of pronounced but open folding in which the dominant structure is the dome. This zone includes the Khaur and Dhulian domes with intervening synclinal notches. Faulting is of only minor importance.

Sohan syncline.

The southerly dips from the crests of these domes merge into the northern flank of the Sohan syncline, a great depression which can be traced from the Murree syncline through the Attock district and across the Indus into the North-West Frontier Province. In the east the axis runs southwest but in the Attock district its direction is almost due east and west and it preserves this direction across the Indus unaffected by the northward bend of the Salt Range.

The south flank of the Sohan syncline in the west is a wide stretch of Upper Siwalik rocks dipping northwards at very low angles. Except for minor warps this northerly dip is uninterrupted. Further east, however, in the Rawalpindi and Jhelum districts the structure is more complex and the southern flank of the main synclinal is made up of a series of narrow anticlines and more open synclines.

The Salt Range.

The nummulitic limestones again emerge from beneath the Siwalik beds in the Salt Range, but the structure here is essentially different from that in the

northern limestone hills. The dips in the limestone plateau which forms the summit of the Salt Range are for the most part gentle and the folds low and open. In the extreme east the Salt Range bends round to the northeast and enters the Murree synclinal at a normal anticline. In the Salt Range proper, where the strike is east and west, and in the great northerly bend into the Indus valley, there is a strong suggestion that vertical movements of uplift and subsidence have played a more important part in the shaping of the range than lateral, compression. Movements in a vertical plane may have determined the general form of the range and lateral compression, effective at a later stage, determined the minor structural features. Anticlines, sometimes closely compressed, have been thrown up along the minor faults accompanied by overthrusting towards the downthrow. Such an interpretation would account for many features otherwise difficult to explain. For example, the Salt Range is a sudden interruption in a region of low dips and is thus in marked contrast to the northern limestone ranges which form part of the Himalayan foot-hills; it swings abruptly northwards into the Indus valley and this sharp change in strike is not reflected in the fold axes further north; folding and over-thrusting along the transverse faults have resulted in a medley of minor folds with variable and adventitious strikes, so much so, that adjacent portions of the range have been folded and overthrust in opposite directions.

Summary.

From the above brief outline it will be seen that in this part of the Punjab there is a gradual passage from the complex folding and over-thrusting of the northern limestone ranges into the low-dipping Sohan basin and the block structure of the Salt Range, the intermediate stages being firstly the isoclinal folding of the foot-hills, next the zone of great strike-faults and synclinal basins, and thirdly, the open but pronounced folding of Jura type in the anticlinal belt. Such a succession of structural types is perhaps unequalled elsewhere in India.

STRATIGRAPHY.

The Limestone-Murree Succession.

Succession at Chharat.

Near the village of Chharat, about five miles northwest of Fatehjang, there is an anticline of nummulitic rocks with Murree beds to the north and south

in which the complete succession in the upper limestones is exposed. The structure of the limestone outcrop was found to be so complex that large-scale detailed mapping was necessary and it was only after some weeks that the structure was understood and the succession established. The section of nummulitic rocks at Chharat is more complete than at any other locality since examined. The following rock series could be distinguished :—

6. Murree sandstones and shales.
5. Basal Murree sandstones with vertebrate remains.
4. Nummulite shales with thin bands of limestone.
3. Thin-bedded limestones and green shales.
2. Variegated shales with bleached limestone bands.
1. Chalky gypsiferous limestones with ochreous beds, passing down into more massive limestones.

All these groups are well exposed in a north and south stream east of Chharat and the section here is illustrated in Plate 5. In this section the beds have been repeated by minor thrust-faults, which are a characteristic feature of the Chharat structure; in another section no less than six of these minor thrusts occur within a mile across the strike.

1. Massive Limestones and Passage Beds.

The lowest rocks exposed at Chharat are massive limestones—the uppermost layers of the hill limestones. These are light grey and white limestones containing a few small nummulites but more generally barren of fossils. In the Kala Chitta hills the limestones are exposed in much greater thickness, dark grey in colour and fetid. The limestones pass up conformably into the next higher stage and the passage beds are of special interest. They are white, chalky limestones containing in places fibrous gypsum and calcite. Some beds are ochreous. A characteristic mineral of this horizon is native sulphur, which occurs as small crystals or thin plates in the more shaly parts of the limestones. This horizon gives rise to the main oil seepages at Chharat, Golra and Rutta Hotar. No definite boundary can be drawn between these gypsiferous, sulphur-bearing limestones and the massive hill limestones.

2. Variegated Shales.

The passage beds are succeeded conformably and without any clear break either in sedimentation or lithology by a series

of brightly coloured shales with thin bleached limestone bands. The shales vary in colour from reddish purple to indigo and green. They contain beds of fibrous gypsum especially abundant in the lower beds. The thin limestone bands are dark grey, becoming lighter in colour and thicker towards the base of the series. The thickness of this stage is 300 to 500 feet.

The shales contain vertebrate remains, *Gavialis* and chelonian plates being the commonest, but as yet none of the forms can be recognised specifically. The bones are preserved in a different manner from those of the Murree and Siwalik and are easily distinguished from them by their highly glazed surface. The grey limestone bands contain *Planorbis*, often in considerable abundance.

It will be seen, therefore, that this stage, unlike those immediately above and below it, is not marine but brackish or fresh-water in origin. The fact that this stage is succeeded by beds which are definitely marine is important in that it proves that this fresh-water series belongs properly to the limestones and is entirely separate and distinct from the Murree fresh-water series.

3. *Limestones and Shales.*

The next higher stage consists of about 100 to 200 feet of green shales with white limestone bands. The shales contain small nummulites in their uppermost beds, but are otherwise barren. The limestones contain abundant casts of lamellibranchs and gasteropods and some beds are crowded with a small thin-shelled *Ostrea*. A larger *Ostrea*, also thin-shelled, occurs less frequently.

This horizon is readily distinguished by its marine fossils from that last described, but there is nothing to indicate the presence of any discontinuity.

4. *Nummulite Shales.*

The highest marine rocks known at Chharat are thin but persistent greenish shales formed almost entirely of nummulite tests. These rocks are so loosely compacted that it is impossible to prepare a hand specimen, for at the first touch of the hammer the rock breaks up into its component nummulites. Occasionally,

thin beds have been cemented to form hard limestone bands but these are exceptional. The only fossil other than nummulites is a thick-shelled globose oyster.

The Nummulite shales resemble certain beds of the Spintangi limestone near Sukkur and in Baluchistan. One horizon near Sukkur contains the same peculiar association of a globose oyster with nummulites. Although the Spintangi limestone is sometimes a loosely compacted nummulitic shale there is generally a calcareous matrix, which is absent from the Punjab beds.

It has been suggested that the Nummulite shales are only the lower part of the Murree basal conglomerate and that the nummulites of which they are composed have all been derived from some lower marine group. This suggestion, however, is quite untenable. I have traced this bed across country continuously for many miles and nowhere has it any appearance of a basal bed. The contained oysters are of special interest in this connection, for they very generally occur with valves united and never shew any signs of attrition. Further, there is an entire absence of the matrix or pebbles that should be present if the Nummulite shales were basal beds of the overlying fresh-water series.

This horizon is extraordinarily persistent in the most complex structure and this character, combined with its distinctive lithology, makes it the most useful bed for mapping purposes of all the limestone series. These shales frequently form narrow inliers along the crests of closely compressed anticlines in the isoclinal region. The older geologists apparently considered these exposures to be interbedded with the Murree series and regarded them as evidence for a passage from one series to another. When these outcrops are traced along the strike, however, the next lower limestone bed can often be found at the crest of the fold and very generally the dips in the Murree sandstones on either flank indicate the presence of anticlinal folding.

No higher marine beds have been seen in any section so far examined and the Nummulite shales are apparently the highest marine series in this part of India.

The great compression which has affected all the limestone series makes it very difficult to determine the thickness of each stage. The Nummulite shales, in the simpler sections, range from 50 to over 200 feet.

5. Basal Murree Sandstone.

The thin basal beds of the Murree series have been fully described by Dr. Pilgrim. They are brown ochreous sandstones with subordinate shales and much pseudo-conglomerate. They are about two hundred feet thick and contain abundant vertebrate remains.

The actual base of the Murree series is well exposed in the stream section east of Chharat. Derived nummulites are scattered irregularly through the basal sandstones and in places there is a conglomerate with limestone pebbles. The junction is irregular but there is no discordance of dip or strike.

The source of the derived nummulites is undoubtedly the Nummulite shales. These shales are easily weathered into a loose nummulitic sand which forms the matrix of the gravels now being deposited by the streams which cross the shale outcrop. The other characteristic fossil of the Nummulite shales, the thick-shelled oyster, frequently occurs more or less water-worn in the Murree basal conglomerate.

The abundant vertebrate fauna yielded by these beds has been described by Dr. Pilgrim. He refers to this horizon as the "Kuldana series" on the assumption that it is the equivalent of the supposed passage beds between the limestones and Murree beds in the Hazara region. It will be shewn below, however, that there is good reason to suppose that the Kuldanas are an inferior Eocene stage equivalent to the variegated shales (stage 2) of the Chharat succession. It seems advisable, therefore, that a local name should be applied to this horizon and I would suggest that the basal Murree bone-beds be called the "Fatehjang zone" after the principal town of the area in which they are best exposed.

6. Murree Series.

The Murree beds are a succession of dark grey or purple sandstones interbedded with purple shales. The sandstones and shales are about equal in amount, individual beds being usually fifty to over a hundred feet thick. The sandstones contain many of the peculiar beds called by Wynne "pseudo-conglomerates", but these are not confined to the Murrees and occur throughout the fresh-water rocks up to the Middle Siwaliks. The Murree shales are reddish-purple in colour, veined with calcite and containing patches of calcareous nodules.

Other areas: Pannoba.

The stages distinguished at Chharat were found to be constant throughout the foot-hills of the northern limestone ranges and their equivalent horizons were recognised in all sections examined subsequently.

In the extreme west of the Attock district a limestone anticline crosses the Indus at Dandit and rises westwards into the Kohat hills. The lowest rocks seen in this anticline have all the characters of the massive grey limestones which form the lowest stage of the Chharat succession. These are overlain by about 700 feet of green shales with white and yellow limestone bands and red shales above. The uppermost bed of the limestone series is a massive limestone about 30 feet thick. In this section the green and red shales appear to be equivalent to the variegated shales (stage 2) at Chharat, the upper limestone bed may be a reduced representative of the limestones and shales (stage 3) which overlie these beds at Chharat, and the Nummulite shale stage is absent.

Wynne has mapped the limestones in this part of the North-West Frontier Province and records that the red and green shales contain *Planorbis* and bone fragments, thus confirming the above correlation and demonstrating the persistent character of this Eocene fresh-water stage.

The Murree rocks of this region call for no separate description for they are similar in every way to the same rocks at Chharat. The basal Murree bone bed has not yet been observed west of the Indus.

Hazara.

Eastwards from Chharat the foot-hills of the Kala Chitta range were mapped in detail up to the Margala over-thrust. The Kala Chitta thrust was found to die out gradually and, one by one, the upper limestone stages emerged along the south side of the fault. Eventually, at the eastern end of the hills, the succession is complete on both the north and south flanks of the anticline and all the Chharat stages are present and easily recognisable. The Nummulite shales form a thin ribbon-like outcrop immediately within the Murree series and they are exactly similar to their counterparts at Chharat. The next lower stage, shales and limestones with internal casts, are well represented in normal position, especially on the north side of the fold; they appear to be somewhat thicker than at Chharat

and less calcareous. Stage 2, the fresh-water shales, are highly gypsiferous, but similar in all other respects to the variegated shales of the Chharat section. The lowest stage, the massive hill limestones, occurs along the centre of the fold as a series of lenticular outcrops marking interruptions in the general easterly pitch.

The anticlinal axis persists beyond Golra and is eventually truncated by the Hazara thrust-fault. The same rock stages are to be seen here as further west but they appear to have suffered severely in the general compression. Both the upper limestone stages are occasionally absent owing either to faulting or unconformity.

The Chharat succession was thus traced continuously across country into contact with the Hazara region described by Mr. Middlemiss. The Kuldana series, which occupies the place of the Subathu beds in the Hazara succession, was examined at Rutta Hotar and this outcrop was traced along the hill-side to within a few yards of the Golra anticline. The lithological characters of the Kuldana shales are exactly those of the variegated shales, stage 2, of the Chharat section. They are purple and indigo shales with thin white and grey limestone bands. No *Planorbis* was found in them but a brief search shewed the presence of small shells suggestive of *Limnæa.*

The main arguments for regarding the Kuldana shales as the equivalent of the variegated fresh-water shales at Chharat are :—

(1) the outcrops of the two series have been traced continuously from one region to the other, the only interruption being at the Hazara fault;

(2) the stratigraphic position of the two series, *viz.*, immediately above and conformable with the hill limestones;

(3) their similar lithology;

(4) the oil-seepage at Rutta Hotar occurs at the junction of the Kuldana shales with the hill limestones and thus occupies an exactly similar position, stratigraphically, to the main oil-seepages at Chharat and elsewhere;

Further reference to the sections described by Mr. Middlemiss suggest that in other parts of Hazara the higher marine stages may be represented.

The Murree unconformity.

If I am correct in affirming the equivalence of these two stages it will be seen that the Kuldanas cannot be passage beds between the limestones and the Murrees. The higher marine stages (3 and 4) of the Chharat succession would intervene if the sequence were complete. Further, the palæontological evidence brought forward by Dr. Pilgrim shews that there is a wide hiatus and true unconformity between the Murree and these limestone stages. The Kuldanas, therefore, must be looked upon as the Subathu beds of the Hazara succession.

Wynne believed that there was no unconformity between the Murrees and the lower nummulitic stages and Mr. Middlemiss adopted Wynne's view when completing his work in Hazara. The marked resemblance between the Kuldana shales and the Murree shales (both must have been deposited under somewhat similar conditions) also pointed to the same conclusion, more especially when it is remembered that the whole of the foot-hill country in which any sort of junction can be observed is a series of isoclinal folds or overthrusts.

The Khaire Murat ridge.

The evidence for unconformity in sections further south is, I think, conclusive. At the eastern end of the Khaire Murat ridge the Murree beds rest directly on the massive hill limestones. Further west, for instance in the Chorgali section described in detail by Wynne,[1] a shale and limestone series intervenes between the Murrees and the hill limestones. These limestones and shales increase in thickness westwards and, at the western end of the ridge, are the only limestones exposed. The limestone and shale series is identical in character and undoubtedly equivalent to the variegated shale series at Chharat. The shales are red, purple, or indigo and the limestone bands contain abundant *Planorbis* exactly similar to the Chharat forms.

The two upper marine stages are absent, as is also the variegated shale series at the eastern end of the ridge. The Murree beds immediately overlying the limestones contain fairly abundant vertebrate remains and have all the characters of the basal Murrees at Chharat.

There is thus good evidence for unconformity and transgression along the Khaire Murat ridge itself and more definitely from a

[1] *Rec. Geol. Sur. Ind.*, Vol. X, pt. 3, p. 118.

comparison of the Khaire Murat sections with that described at Chharat. The Murree limestone boundary along the north side of the ridge is normal and there is no trace of faulting. In the Chorgali section there is a well-marked basal conglomerate containing large sub-angular boulders of limestone and derived nummulites. In the western part of the range this basal conglomerate is not so well-marked, but it is replaced by a hard massive nodular limestone bed about ten feet in thickness which suggests a re-cemented limestone conglomerate.

The Salt Range.

In the Salt Range the only representative of the northern limestones is the massive nummulitic limestone of the plateau. This limestone is similar in lithological character to the hill limestones of the Khaire Murat ridge and the Kala Chitta hills and must be regarded as their equivalent. The main difference is the reduced thickness of these rocks in the Salt Range. No representatives of the upper limestone and shale series (Subathu) are known.

In that arm of the range which runs northwards into the Indus valley the uppermost limestones contain native sulphur and oil and there is thus a strong indication that we have here the "passage beds" at the top of the hill limestones of the Chharat succession. Further, in this area the basal beds of the overlying Siwalik rocks contain derived nummulites similar to those in the Murree basal bed at Chharat and, in view of the supposed source of these nummulites, there is a suggestion that the Subathu beds are not far to the east below the Siwalik base.

In many sections in the Salt Range there is a well-marked conglomerate of limestone boulders at the junction of the limestones and Siwaliks. In places this conglomerate is over twenty feet thick but elsewhere the conglomerate is absent and its place taken by a hard nodular limestone bed similar to that at Khaire Murat.

In a later paragraph it will be shewn that the basal beds of the Upper Tertiary fresh-water system in the Salt Range are of Lower Siwalik age and that the whole of the Murree series is absent owing to unconformity and overlap.

Nomenclature and correlation.

There seems little room for doubt that Wynne was correct in correlating the upper limestones and shales of the succession in this part of the Punjab with the Subathu beds of the Simla region and Jammu. In Simla and Jammu, however, the Subathu beds are described as entirely marine and there is no mention of any subdivision into two or more stages. The section of these rocks at Chharat thus appears to be more complete and is known in greater detail than that of the region in which they were first described. Pending a more detailed examination of the Subathu beds in the Simla region it seems advisable to adopt local names for the two divisions, the one fresh-water and the other marine, which have been distinguished in the Subathu beds of Chharat.

The lower fresh-water shales (stage 2) will be referred to as the "Lower Chharat stage" and the two upper marine series—the Nummulite shales and the limestones and shales—will be placed together in the "Upper Chharat stage." Both the Chharat stages are present along the foot of the Kala Chitta and Margala hills, but only the Lower Chharat stage is known at Khaire Murat. It is the Lower Chharat stage which is equivalent to the Kuldanas of Hazara.

The complete succession at Chharat with the nomenclature suggested above is :—

Murree series.

Fatehjang zone.

Unconformity—

Upper Chharat stage .	{ Nummulite shales Limestones and shales.
Lower Chharat stage .	. Variegated shales with *Planorbis* and bone fragments.
Hill limestones . .	. Massive limestones with passage beds above.

Any attempt to correlate this section with those of Baluchistan and Sind must be fraught with considerable uncertainty and it is doubtful whether further work, other than the detailed study of the contained faunas, will assist us, as there is a wide gap between the Subathu beds of the North-West Frontier Province and the most northerly outcrops of the Khirthar stage of Baluchistan in the Dera

Ismail Khan and Dera Ghazi Khan districts. There is, however, sufficient parallelism in the two successions to suggest a possible correlation. The Upper Chharat stage has certain characters in common with the Spintangi limestone and both the Nummulite shales and the limestones and shales are similar to the individual beds of which the Spintangi limestone, as seen at Sukkur and in the Marri Bugti Hills, is composed.

The tentative correlation of the Upper Chharat stage with the Spintangi limestone receives further support from the fact that both are underlain by a series of fresh-water gypsiferous shales—the Lower Chharat stage of the Punjab and the Ghazij shales of Baluchistan.

The Punjab Hill limestones below the fresh-water stage find their Baluchistan equivalent in the thin nummulitic limestones and shales at the top of the Dunghan limestones. The *Cardita beaumonti* zone which occurs lower in the Dunghans is paralleled by the *Cardita beaumonti* shales at the base of the Salt Ranges nummulitic limestones and is the only palæontological reference horizon known, as yet, to be common to the Baluchistan and Punjab successions.

This correlation, if correct, would be of special interest from an oil point of view, as it would indicate an identical horizon for the main oil-seepages of the two regions; most of the Baluchistan seepages are located at the junction of the Dunghan beds with the overlying Ghazij shales just as the Punjab seepages are at the junction of the hill limestones with the fresh-water shales of the Lower Chharat stage.

The above correlation is given in tabular form at the end of this paper.

The Murree-Siwalik Succession.

In the Chharat section two stages of the Murree series were recognised, *viz.*, the thin basal beds with vertebrate remains, or Fatehjang zone, and the purple sandstones and shales which form the Murree series proper. The Fatehjang beds have been observed only in the Chharat anticline and along the north side of the Khaire Murat ridge. The complex structure of the isoclinal region, which corresponds roughly with the Murree outcrop, makes it extremely difficult to ascertain the thickness of this great group, to attempt its subdivision, or to determine its relations to the overlying Siwaliks.

Wynne mapped the Mianwali fault as the southern boundary of the Murree outcrop. South of the fault he maps a narrow belt of Murree beds along the north flank of the Salt Range and three Murree inliers on the north flank of the Sohan syncline. With the exception of one inlier (along the crest of the Khaur anticline) all these supposed Murree rocks must be referred to the Lower Siwaliks. North of the Mianwali fault, at about the 11th mile on the Pindigheb-Basal road, I have found vertebrate remains and true conglomerates, which suggest that these rocks also are Siwalik in age and not Murree as shewn on Wynne's map. With these few exceptions, however, Wynne's boundary has been confirmed by my own more deliberate work.

Upper Murree stage.

North of the Khaire Murat ridge there is a fairly continuous section through Murree rocks dipping northwards with local complications. The lower part of this section is in purple sandstones and shales of the usual Murree type, but there is a distinct change in the upper beds. These are of Siwalik type and at the time the section was examined they were mapped as such. Later work has shewn that the top of these beds and the base of the next overlying stage should preferably be regarded as the Murree-Siwalik boundary and therefore the uppermost portion of the Khaire Murat section must be relegated to the Murree series. They are easily distinguished from the purple Murree beds and therefore constitute a separate stage—the Upper Murree stage. These rocks are pepper and salt sandstones with red and grey shales. The sandstones are much softer and more easily weathered than the sandstones of the Lower Murree stage. Similar beds were observed northeast of Rawalpindi but here their relations to the adjacent rock groups are obscured by alluvium. The same rocks can be recognised also on the south side of the Khaire Murat ridge, where they occupy a narrow zone of complex structure between the limestones and the basal Siwalik beds.

This Upper Murree stage may correspond with the Kasauli beds of the Simla region. The Dagshai beds are similar in lithological character to the Lower Murree stage and the Kasauli beds resemble the Upper Murrees in that their sandstones are softer and lighter in colour than the Dagshai sandstones. The Upper Murree rocks differ from the Kasauli beds in that they are not essentially a sandstone series, but are composed of sandstones and shales in about equal proportions.

Siwalik series: Kamlial beds.

The various zones into which the Siwalik rocks have been subdivided are well exposed in the open structures on the north flank of the Sohan syncline. The lowest rocks exposed here, with the exception of the Murree inlier at Khaur, are massive sandstones and purple shales having a marked resemblance to the rocks of the Lower Murree stage. They are distinguished from the latter by the fact that they contain abundant vertebrate remains. These rocks have been named the "Kamlial beds" after the large village of that name near the area in which they are best exposed; Kamlial itself is situated on rocks at a higher horizon (Plate 4).

The Kamlial beds are about 900 feet in thickness. The sandstones are harder and more massive than either the overlying Siwalik sandstones or the Upper Murree beds and in consequence the Kamlial beds form pronounced strike ridges which can be traced across country for many miles. The best example is the Chirpar hills, which run parallel to the Khaire Murat ridge and then eastwards across the Rawalpindi district into Jammu. These beds are also responsible for the scarps round the crest of the Khaur dome.

The Kamlial beds contain the lowest known vertebrate fauna above the Fatehjang zone and for this reason they have been mapped as the basal beds of the Siwalik system in this part of India. This has since been confirmed by Dr. Pilgrim after an examination of their fossils; he correlates the Kamlial zone with the lowest vertebrate horizon of the Manchhar series in Sind.[1]

Murree-Siwalik junction.

The relations of the Kamlial beds (basal Siwalik) to the next underlying stage (Upper Murree) are therefore of special interest. In the Chirpar hills the two stages are seen in contact without discordance of strike or dip, but the structure here is so severely compressed that it would be unsafe to draw any definite conclusions as to the presence or absence of unconformity from this section alone. In the Khaur dome, however, the structure is perfectly simple. Inside the pronounced ridges formed by the Kamlial beds there is a narrow outcrop of soft white sandstones and red shales similar to the Upper Murree beds of the Khaire Murat region. Over 1,500 feet of these rocks are now known to be present at

[1] *Rec. Geol. Sur. Ind.*, Vol. XLVIII, p. 98 (1917).

Khaur and their lithology and stratigraphic position indicate that they are the Upper Murree beds of more northern sections. This outcrop extends along the crest of the dome for over four miles and both surface evidence and well-logs shew an exact parallelism of structure between the Upper Murree and the Kamial beds. The actual junction is well exposed and there is no trace of a basal conglomerate. My colleague, Dr. Bleeck, has observed minor unconformities between the sandstone and shale beds, but these occur at various horizons and are of only local significance.

Thus, in the only sections in which the Murree and Siwalik series are known in simple contact, there is no evidence for unconformity; on the contrary, there is a clear indication that deposition was continuous from one series to the other.

Age of the Murree series.

The Lower Manchhar horizon of the Bugti hills is separated from the Gaj bone bed by a pronounced unconformity.[1] We have seen above, however, that in the Punjab there appears to have been continuous deposition from the Fatehjang zone (Gaj) to the Kamlial beds (Lower Manchhar). The Murree series thus occupies the hiatus in the Bugti succession and is equivalent (with the Fatehjang zone) to the Gaj stage of the Sind Tertiary.

Lower Siwaliks: Chinji beds.

Overlying the Kamlial beds at Khaur and south of the Chirpar hills is a series of red and grey shales with subordinte soft sandstones. These beds contain abundant vertebrate remains and this distinguishes them from the Upper Murree beds which they resemble in lithology. These beds are the Chinji or Lower Siwalik stage of Dr. Pilgrim's papers. They occupy the crest area of the Dhulian dome and occur in narrow zones along the main strike-faults. They are about 4,000 feet in thickness and they appear to rest quite conformably on the Kamlial beds.

Middle Siwalik.

The rock immediately overlying the Chinji beds is a thin hard sandstone which forms a low but pronounced ridge all round the Chinji outcrop and is especially well-marked on the south flanks of the Khaur and Dhulian folds. Above this bed is a series of sandstones with subordinate orange or brown shales. The sandstones are conglomeratic with

[1] Pilgrim, *Pal Ind.*, New Series, Vol. IV, Mem. No. 2 (1912).

pebbles of limestones and quartzites. Dr. Pilgrim records a prolific fossil zone some distance above the base of this series.[1]

Upper Siwalik.

There is an increase in the conglomeratic character of the Middle Siwalik sandstones as we pass upwards and there seems to be a gradual passage into massive conglomerates of considerable thickness. Near Injra, in the centre of the Sohan basin, these conglomerates are interbedded with white sandstones and bright red clays.

The conglomerates overlap many of the older rocks and it seems possible that they are continuous with the recent conglomerates of the alluvium and river gravels. Both the older conglomerates and, to a lesser extent, the recent alluvium have been affected by earth movements. The structure in the massive conglomerates conforms to that of the underlying formations except when they overlap on to older rocks. An interesting instance of movement in recent beds is to be seen at Golra on the south side of the Kala Chitta anticline where a conglomerate of limestone boulders, which apparently forms the base of the alluvium, dips vertically, indicating considerable earth movement since its deposition.

The Salt Range section.

The section along the north side of the Salt Range down to the base of the Chinji beds is quite clear and the Middle and Lower Siwalik rocks are similar in thickness and lithology to the same rocks on the north side of the Sohan basin. The Upper Siwalik conglomerates are underlain by the Middle Siwalik sandstones at the base of which is a well-marked ridge sandstone. The village of Chinji is situated on a dip slope and scarp formed by this bed. The Chinji beds of the Salt Range are also similar in thickness and lithology to the corresponding rocks in the Khaur and Dhulian anticlines.

The Chinji beds south of Chinji are underlain by about 600 feet of massive sandstones with a few thin shales. The sandstones contain fossil wood. There is a perfectly gradual passage from the Chinji beds to this sandstone series. It will be seen, therefore, that these sandstones occupy a corresponding position to the Kamlial beds of the northern sections and must be regarded

[1] *Rec. Geol. Sur. Ind.*, Vol. XL, p. 191 (1910).

as equivalent to them. They are therefore of Lower Siwalik age and not Murree as was claimed by Wynne.

These beds differ in some respects from the northern Kamlial beds more especially in the absence of purple shales and vertebrate fossils. These differences, however, are sufficiently explained by the different conditions under which the rocks were deposited; the Kamlial beds in the northern sections indicate merely a slight alteration in the conditions under which the Upper Tertiary rocks were laid down; they form part of a continuous series of fresh-water deposits. In the Salt Range, however, these beds are the actual base of the fresh-water Tertiary for they rest with unconformity and a marked basal conglomerate on the limestones. Vertebrate fossils have been recorded from near the base of this zone by Theobald.[1]

Both to the east and to the west of the Chinji section these basal beds change in character; they increase in thickness and include a larger proportion of purple clays. They are then similar in character to the Kamlial beds and Lower Murree stage, but from their stratigraphic relations and contained fossils there seems no doubt that these beds are of Lower Siwalik age and equivalent to the Kamlial beds of northern sections.

Summary.

There appears, therefore, in this part of India to be a continuous section from the lowest Murree rocks to the Upper Siwaliks and the following stages can be distinguished :—

Upper Siwalik		Conglomerates and sandstones.
Middle Siwalik		Sandstones and subordinate shales.
Lower Siwalik	Chinji beds	Red shales and sandstones.
	Kamlial beds	Dark sandstones and shales of Lower Murree type. Massive sandstones and few shales south of Chinji.
Upper Murree		Soft sandstones and red shales of Siwalik type.
Lower Murree		Purple sandstones and shales.
Fatehjang zone		Brown sandstones with vertebrates.

[1] Manual of the Geology of India, 2nd Ed., p. 355.

Acknowledgments.

It will be seen from my frequent references to his papers how much I am indebted to Dr. Pilgrim and it was only at his suggestion that I added the brief description of the Murree-Siwalik succession. The correlation of Murree and Siwalik horizons in the adjoined table is based entirely on Dr. Pilgrim's work. I have also to thank other members of the Geological Survey, more especially Drs. Hayden and Pascoe and Mr. Cotter, for much friendly criticism and advice with regard to the present note and for constant and greatly valued assistance throughout the course of my prospecting work in India and Burma.

Correlation Table of the Punjab Tertiary Succession.

Sind.	Bugti Hills.	N.-W. Punjab.	Simla Region.
Upper Manchhar.	Upper Siwalik.	Upper Siwalik. Middle Siwalik.	Upper Siwalik.
Lower Manchhar.	Lower Siwalik.	Chinji beds. Kamlial beds.	
Gaj.	Bugti bone beds.	Upper Murree. Lower Murree. Fatehjang beds	Kasauli beds. Dagshai beds.
Nari.	Absent.	Absent.	Absent.
Khirthar. Laki.	Spintangi limestone. Ghazij shales.	Upper Chharat stage Lower Chharat stage.	Subathu series.
Ranikot (?)	Dunghan limestones.: Limestones and shales. *Cardita beaumonti* zone.	Hill limestones. *Cardita beaumonti* zone.	Absent.

N.B.—Thick lines indicate unconformities.

LIST OF PLATES.

NOTE ON THE AQUAMARINE MINES OF DASO ON THE BRALDU RIVER, SHIGAR VALLEY, BALTISTAN. BY C. S. MIDDLEMISS, C.I.E., F.G.S., AND LALA JOTI PARSHAD, B.A., F.G.S., *Mineral Survey of Jammu and Kashmir State.* (With Plates 6 to 10).

Introduction.

AQUAMARINE is one of those gem-stones of moderate value, which, though never comparable in this respect either with the diamond, ruby, sapphire, or with its sister stone the emerald, is nevertheless a pleasing and attractive stone for many purposes, and, whilst always commanding a fair amount of patronage, may at any moment become of considerable importance and in great demand whenever fashion so dictates.

Occurrences in India.

Whilst it has many natural homes in other parts of the world its occurrence in any quantity and value in India has hitherto only been recorded from Padiyur near Kangayam in the Coimbatore district of Madras; and, even there, the source has either been lost or exhausted, for the locality has remained unworked since the year 1818. In any case the Padiyur area (which one of us had the opportunity of seeing some 20 years ago) is very deeply covered in by alluvium and other surface deposits, so that no extensive outcrops of the immediate matrix or surrounding country rock are at all likely to be discovered.

Kashmir deposits.

Hence the Kashmir deposits of Daso are almost unique in India at present as a source of this stone; and, inasmuch as they give promise of great richness and extension, in fully exposed outcrops, in a country where soil and vegetation are restricted, it is anticipated that they may presently enjoy a practical monopoly of the attention of seekers after this much admired gem.

History of their discovery.

The history of their discovery is briefly as follows:—In July 1912, when one of us (Mr. Joti Parshad) was investigating the serpentine occurrences in the Shigar valley of Skardu Tehsil, in the course of his professional work for the Mining Department in

Kashmir, he accidentally came across a piece of aquamarine in the possession of one Abdul Rahman, a Zamindar of Niyit village (near Daso) in the Braldu valley. On enquiry, it was ascertained that a *shikari*, by name Ghulam, had found similar stones, but was unable or unwilling to indicate their exact locality. After the offering of a small reward, a parcel of beryl crystals was forwarded to the Mining Department by the Tehsildar of Skardu, in October 1912. These, though not clear aquamarines, indicated that somewhere among the hills of the Basha and Braldu drainage area gems of this kind might be found. Eventually, after further steps had been taken, Lala Joti Parshad was deputed by the Durbar in 1915 to conduct a regular search in the hills of that neighbourhood, and at last he had the satisfaction of coming upon beautifully clear aquamarine crystals, in a thick vein of pegmatite, at the village of Daso lying a few miles south of and under Ganchen peak. Lala Joti Parshad visited the area again in 1916, when he excavated considerable quantities of the gems; and, in the summer of last year (1917) the two authors together spent 12 days on the mines examining their extent and geological conditions, and making test experiments as to their productivity. At the same time evidence was obtained showing that other veins within a few miles of Daso also yield beryls and aquamarines, and that these stones are also found even further away up the Braldu and Basha valleys, and also in the Rondu neighbourhood. At present, only the area immediately near Daso village has been thoroughly investigated by us, and the results set forth in this paper are entirely drawn from that area.

Locality.

The exact locality is at the village of Daso (lat. 35° 43′, long. 75° 31′) situated on the right bank of the Braldu river a few miles above its junction with the Shigar river. It lies at a height of about 8,300 feet above sea-level, the route to it being by bridle-road and foot-path from the well-known orchards of Shigar, and the distance about 27 miles. No great difficulties are found on the route, except that the Braldu river at Daso is a rapid and turbulent stream, of great volume, descending from the Biafo, Baltoro and other glaciers; the usual method of negotiating which is by a raft of inflated goat-skins. Details as to the route to Shigar and approximate transport rates will be given later (see page 172). Daso is a considerable village of some 100 houses placed on terraced alluvial fans, and bearing

fields of barley and other grains and a few scattered apricot, apple, walnut, poplar and willow trees, all of which (as is the custom in this arid region) are irrigated from perennial glacier-fed side streams descending from the fine peaks round Ganchen (marked on the Atlas of India Sheet as over 21,000 feet) to join the Braldu. Above the fields the bare hillsides rise steeply and often precipitously in cliffs and slopes of rugged gneiss. Daso possesses a population of hardy (albeit goitre-stricken) mountaineers, who take kindly to the task of the rock-work incident on excavating for aquamarine.

Geological formation —biotite-gneiss.

The prevailing geological formation at Daso, and for many miles in all directions, is massive biotite-gneiss, interrupted at intervals by extensive veins of coarse pegmatite—the matrix of the aquamarine. The gneiss possesses a distinct foliation, which is often wavy and puckered, the different layers showing varying coarseness of grain and amounts of the component minerals. The paler layers sometimes expand into the appearance of lenticular contemporaneous veins with porphyritic felspar. But they continue to have the ordinary minerals of the gneiss and not those of the pegmatite veins, these being a very simple aggregate of quartz, orthoclase and biotite with a little plagioclase, which give a black and white banded appearance to the rock.

Pegmatite veins.

The veins of pegmatite which course through the biotite-gneiss at intervals must be considered to be distinct from the lenticular contemporaneous veins. They cut through the gneiss in all directions and in a most irregular way. Some of the pegmatite is fine-grained (though usually coarser than the material of the gneiss), but that of the larger veins, and of those most productive in aquamarine, is very coarse; and, as is especially well seen at mine no. 1, has sometimes segregated into parallel bands of quartz and felspar. The minerals represented are primarily quartz and orthoclase with some albite. Next in order of frequency come tourmaline and muscovite, and then beryl and a little deep-coloured, clear, garnet. The orthoclase, white or pale cream-coloured, is in great poikilitic plates from a few inches to a foot or more across. The tourmaline is black and occurs in prisms some 2-4 inches long, the long axes lying in all directions, but it is occasionally aggregated into denser patches and masses of smaller crystals and veinlets. It decomposes into deep brown stains visible along joints and the cleavage of the felspar. The

muscovite is scattered in isolated scales sparingly throughout the rock, and also forms roughly spherical aggregates of clusters of plates disposed radially from a centre, some of these being ¾ inch, or more in diameter.

Whilst the smaller veins, and the outer marginal parts of the thicker veins, are composed of the minerals aggregated as above, the central parts of the thicker veins (such as that in mine no. 1) have their content differentiated into quartz and felspar layers or masses, the most productive zone in beryl being the line of junction between the two, and also within the felspar for some distance from the quartz. The quartz-aggregation layer, or mass, contains little and unimportant crystals of beryl. At a few places in mines no. 1 and no. 2 the felspar layer (which otherwise is hard rock) on blasting yields drusy or miarolitic cavities (or cavities filled with kaolin) which are the chief source of the clearer gem aquamarine. On piercing a cavity of this kind, one can frequently look inside and see the transparent, green, aquamarine prisms projecting into the cavity from all sides. A special description of the beryl and aquamarine content will follow presently.

Ultrabasic dykes.

Ordinary basic dykes are absent in the Daso area. One small peridotite dyke, occurring a short distance on the path to Upper Daso from mine no. 1, is composed of pyroxene, olivine and biotite in large scattered and ragged plates in a fine-grained or micro-crystalline greenish ground-mass of highly refracting and strongly doubly refracting material, not yet determined.

General features and rock distribution.

The physical features, rock distribution, and mine localities of the Daso area can best be appreciated from the photographs, plan, sections and outline view (Plates 7 to 10). The general view of the mine area (Plate 8) speaks for itself as regards the general topographical features. The plan (Plate 10), on a scale of 16 inches to 1 mile, was drawn during our stay there specially to illustrate the subject matter of this paper. It, and the outline view drawn by *camera lucida* show the gently inclined, cultivated alluvial fans of Lower and Upper Daso, separated by a steep, and frequently precipitous, line of cliffs of biotite-gneiss, some 300-500 feet in height. Among this the actual disposition of a large number of pegmatite veins has also been depicted, together with the small openings that at present constitute the mines, namely

mine no. 1 on the path between Lower and Upper Daso and lying just above the 550-foot contour, mine no. 2, low down at the 200-foot contour near to the river, and the vertical cliff-working named "Ladder hole" not far from this between the 200- and 250-foot contours. Besides this there are two more places, on the foot-path joining the two Dasos, marked "quarry," where a small amount of excavation has been done.

Direction and disposition of the pegmatite veins.

So far as one can say at present, there is but little system discernible in the arrangement of the veins of pegmatite in the country-rock. They do not follow any noticeable fissures, and each, as exposed at the surface, runs a short course and then disappears by thinning away or branching. There may occasionally be parallelism between the direction of a vein or part of a vein and the foliation of the gneiss, but this does not seem to be of much importance. It is noticeable that the strike of the foliation of the gneiss changes abruptly from about W. N. W.—E. S. E. along the path between the two Dasos to N. N. E.—S. S. W. along the line of the cliff south of Upper Daso, and that the intervening portion of the cliff has a marked bend in it at a point where two ravines descend from the western end of the cultivated land of Upper Daso. It is not impossible that this indicates a fault, or an equivalent wrench of the gneiss at this place, and it is certainly more than usually prolific in pegmatite veins at this point, namely the N.—S. trending group linking mine no. 2 with the two "quarries."

Dimensions of the pegmatite veins.

This irregularity or lack of apparent system in the run of the veins, as also in their shape, which is likewise irregular as displayed at the surface, makes it impossible accurately to estimate their length, breadth and thickness, and so to deduce their cubic contents. As regards length, the exposed parts vary from a few yards to as much as 150 or 200 yards, but of course we know nothing of their unexposed course within the rock. Similarly, their breadth or thickness cannot be estimated, except very generally, because one never knows in which direction in any given vein to measure them. It is certain that many are, at least, several feet, perhaps yards, in thickness, and that is all one can say. That the amount of pegmatite easily accessible to a moderate depth, in the area depicted between the two Dasos (that is to say in a tract of hill-side ½ mile long by about ¼ mile broad) totals a very respectable figure, seems

fully assured, and may be regarded as difficult to exhaust during very many years of strenuous mining. One does not like to use the word "inexhaustible" if one can help it, but, taking into consideration not only the restricted small area here described, but also the neighbouring areas within a mile or two where similar pegmatites with beryl are known; and secondly, considering the fact that beyond this again in the Basha valley and Rondu region reports have reached us of aquamarine-bearing pegmatite being found there as well, I think one would be justified in saying that the known matrix of the aquamarine in this part of Baltistan, generally, is practically inexhaustible.

The mines at present.

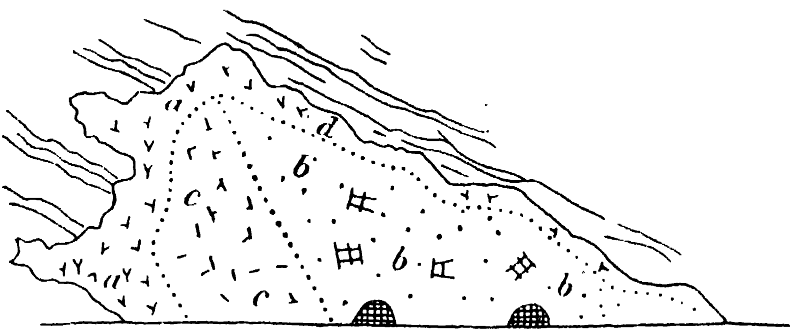
The sections through mines no. 1, no. 2 and "Ladder hole" show the general slope of the rocky cliffs on which excavation has been in progress, and at the same time illustrate how insignificant—relatively to the amount of pegmatite in sight—has been the excavation of it so far undertaken. From the point of view of this paper it is immaterial to describe the so-called mines in any further detail. They are really just holes and open quarries on slopes and ledges of rock whence about 1,000 tons of rock have been blasted out. The photographs will give a better idea than words of their scope and general appearance. Notwithstanding their insignificantly small dimensions they are perfectly capable of furnishing important and reliable estimates as to the richness of the rock in aquamarine; for the nature of this mineral, as well as its being a regular accessory in most of the exposures of the pegmatite so far opened up, argues its probably fairly regular, presence in the pegmatite of the Daso group of veins, be it near the surface or deep below ground. Unlike the case of most metalliferous ores, that are frequently secondary in origin and that change rapidly in depth, there is no necessity with a mineral of this kind to prove each lode by boring or other deep mining methods. Furthermore, the number of the veins, even in the restricted area within an easy scramble round Daso, is so very large that, should some of them prove barren on opening them up, it would only be necessary to try others of the large assortment available.

It does not follow from this that similar pegmatite, in country-rock of the nature of this biotite-gneiss, will yield the gem forms of aquamarine at places considerably distant from the immediate vicinity of Daso. Each separate locality, when the distance from

any proved locality amounts to miles instead of hundreds of yards must be separately tested. For the present and perhaps for a long time, the assemblage of veins at Daso will furnish abundant matrix rock for all likely demands. In the course of time, as these become exhausted or too deep or difficult to work, others must be tested further afield.

Arrangement and distribution of the beryl crystals in the matrix.

The actual occurrence of the beryl and aquamarine in the pegmatite may best be illustrated by reference to particular exposures made by digging at the mines. Mine no. 1 so far as the operations have gone up to date, reveals an exposure 37 feet wide in an upward direction and 65 feet long along the foot-path in what is probably a direction somewhat diagonal to that of the real thickness. The annexed figure shows the composition of the vein thus exposed. The outer marginal aureole marked (*a*) is the ordinary pegmatite of fine to medium grain. It is some 6 feet wide, but thinner on the right of the figure, which corresponds to the eastern side of the exposure.



Within this are areas marked (*b*) and (*c*) respectively; (*b*) represents the practically barren quartz with a few masses of felspar here and there and (*c*) is wholly felspar with beryl dotted about it, the latter more closely collected in the occasionally-found drusy cavities, and as the line of division between it and the quartz is reached. In such places as these the prisms of beryl approach one another so closely that the open hand will cover 2 or 3 of them, and lumps, broken away by blasting or quarrying, of the size of a man's head will frequently yield a large handful of them. Whilst the majority of these will be common opaque beryl, or the merely translucent deeper green variety, a few here and there will be transparent

enough for cutting. As already remarked the drusy cavities usually yield a large quantity of this transparent green variety.

Mine no. 2 is much less regularly arranged in the above way, so far as can be seen in the part exposed by mining, which is not as extensive as that at mine no. 1. The arrangement is more "spotty", so that the places where the beryl appears show no special alignment in any one direction.

Crystal forms.

The beryl crystals appear in the usual six-sided prisms much longer in the direction of the vertical crystallographic axis than at right angles to this. They very seldom show any terminal faces, but a few exceptional samples that alone were collected have a few such faces developed. We are indebted to Mr. D. N. Wadia, Professor of Geology in the Prince of Wales College, Jammu for determining these for us in the College laboratory. Four specimens were sent to him and he reported on them as follows:—

"The aquamarine crystals possess two peculiarities, (1) the terminal developments, which are rather rare in beryl, and (2), which is more exceptional, the presence, of faces in the prism zone, belonging to prisms other than those of the 1st and 2nd orders. The striations are due to this cause.

With regard to the terminal faces on three of the aquamarine crystals, I enclose 3 sketches: (*a*) is a combination of the hexagonal pyramids of 1st order with base. (*b*) is a combination of pyramids of the 1st and 2nd orders, with prominent base. There are two pyramids p_1 and p_2 in the first form. (*c*) is a combination of 3 forms—base, hexagonal pyramids (*p*) and the dihexagonal pyramid (*v*). Here, in the prismatic zone, is an interesting face between (*a*) and (*m*). Such faces are rather rare and Dana does not mention or figure them in his "System" in which he gives a large number of combinations seen in beryl. (*d*) the fourth aquamarine crystal is very interesting. It encloses another prismatic crystal in crystallographic orientation with itself."

Size of the crystals.

The size of the coarse, opaque and feebly translucent beryls is generally from $\frac{1}{2}$ inch to as much as 2 or 3 inches in width and from 2 to 6 inches or more in length. The transparent, quite clear quality are invariably smaller as a whole, averaging from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches wide and 2 to 3 inches long in the more perfect specimens, such as occasionally break out of the rock. But, as generally obtained

in broken pieces, owing to the blasting, quarrying and cobbing of the hard rock, their sizes vary from that of filberts to walnuts, together with a great quantity of smaller shattered pieces and dust.[1]

Colour and transparency.

Undoubtedly as a whole the Daso aquamarines are of a pale, or perhaps one should say delicate tint (for it is in no sense a diluted or washed-out tint), but the shade has the true aquamarine value, and the limpidity, especially noticeable when the gems are cut 'brilliant' fashion, probably makes up for this in some measure. The colour at night by artificial light is considerably deepened and more vivid. It is, however, no use arguing against the vagaries of fashion, and inasmuch as the Daso aquamarines seldom show great depth of colour, in this one respect they fall short of the highest standards of excellence now in vogue. This will in some measures detract from their value in the markets of the world, where as much as £2 a carat may be realized for the deepest coloured, perfect, cut gems.[2] £2 a carat is an ideal price that it will not be necessary to aspire to in order to make the Daso aquamarines a commercial success.

Undoubtedly the colour of the Daso stones varies a good deal within well defined limits in the majority of cases, from those which appear almost colourless when cut, to others which in the lump-form are a very beautiful and characteristic, vivid greenish blue or bluish green (the balance between the two colours being fairly even). The grass-green or emerald tint is very seldom approached. A very few small pieces show deeper and more violet blue tints in patches, there being no gradation in colour between them and the ordinary tinted stones. These, however, are not very transparent and are merely mentioned here because of the possibility that other better pieces may be found when the area is regularly worked. One only, so far found, has the "cornflower" blue tint and it is doubtful whence this was obtained, as it was brought in by one of the watchers and said to come from near Rondu.

The depth of colour of the ordinary clear form of the Daso material naturally increases with the size of the stone. As stones well over 10 carats can commonly be cut into fairly large gems for necklaces, pendants and brooches the increased depth of colour thus gained will enhance their consequent value.

[1] One exceptionally large crystal 10 inches long and 5 inches in width weighing about 13 lbs. was collected from these mines in 1915.

[2] Herbert Smith "Gem-Stones" 1913, page 194.

Besides the transparent variety just described and the dull almost opaque, common beryl of not very attractive tint, there is also found an intermediate variety which is translucent or semi-transparent. This generally occurs of rather larger size than that attained by the clear variety, and in large lumps is of a delightful colour. Though unsuitable for cutting in facets it looks very well in smooth *cabochon* form. Occasionally an opalescent variety of this shows appreciable asterism.

Relative abundance of the stone.

It is now necessary to say something as to that very important aspect of the case—the quantity available in proportion to rock excavated. During the 10 full working days spent at Daso, each day's takings were sorted roughly into certain qualities and weighed, only the very opaque, rough, material being altogether rejected. These have subsequently been resorted at head-quarters into :—

		Weight in Grams.
A-1 quality . .	Large and clear . . .	1,586·10
1st quality . .	Small and clear . . .	1,516·12
2nd quality or intermediate (large).	Translucent or semi-transparent but of good colour.	2,099·25
2nd quality or intermediate (small).	Small fragments . . .	1,247·88
3rd quality . .	Rough beryl . . about	102 lbs.

Owing to the steep slopes below the mines, the operations of blasting and quarrying sent a large portion of the rock excavated bounding down hill beyond recovery for weighment purposes. The rather irregular shape of the openings also precludes any very accurate estimate of their cubic contents. A rough estimate however shows that at mine no. 1 a slice of rock $15' \times 20' \times 4'$ or about 1,200 cubic feet was excavated and at mine no. 2 similar slices $(16' \times 5' \times 4')$ *plus* $(15' \times 4' \times 4')$ or about 560 cubic feet. We have, however, a third method of reckoning that promises better perhaps than either of the others, namely one in terms of time spent, labour employed, explosive used, wages paid and so on.

These factors arranged in tabular form are as follows :—

No. of days.	No. of men employed.	Price of explosive.	Wages to workmen.	Charcoal.
		Rs.	Rs.	Rs.
10	25	65	106	7

Thus, in 10 days, with 25 men employed in excavating whose wages amounted to Rs. 106 with the expenditure of Rs. 65 worth of explosive and Rs. 7 worth of charcoal (for sharpening the tools), that is to say at a total cost as regards mechanical work of Rs. 178, the above quantities of aquamarine and beryl were realized. There were probably unavoidable losses in these quantities by some stone not being recovered owing to its dispersion over a large area of precipitous rock and also perhaps by petty thefts. These would be reduced if working under commercial conditions was continued for any length of time, but probably could not be eliminated entirely.

Market rates of the gem-stone.

From some experimental sales of the uncut stone and gems fashioned from it by the cutters in Delhi and Lucknow, which Lala Joti Parshad made in 1916-17, and from subsequent sales, we have put down the price of A-1 quality uncut at 6 annas a carat, reckoning the carat at 0·20 grams=3·0864 (roughly 3·1) grains. The price of other qualities are less easy to estimate, but for the 1st quality (small and clear) we shall be on the safe side putting 2 annas a carat, and for the 2nd quality or intermediate (large) 1 anna a carat.

Values of results of experimental working.

Neglecting the 2nd quality (small) and all the rough beryl we may then deduce the total value of the ten days' takings as :—

	Grams.	Carats.	@ Rs.	A.	P.	Rs.	A.	P.
A-1 quality	1,586·10 –	7,930	0	6	0	2,973	12	0
1st quality (small) . .	1,516·12 –	7,580	0	2	0	947	8	0
2nd quality or intermediate (large.)	2,099·25 –	10,495	0	1	0	655	15	0
		TOTAL .				4,577	3	0

Deducting from this sum Rs. 178 for cost of labour, explosives, etc., as reckoned above, there would be realized Rs. 4,399-3 for a period of 10 days, or Rs. 13,197-9 per month to cover transport, supervision, sale charges and profits. This sum could easily be doubled under the same supervision by employing twice the amount of labour, explosives, etc.

All this is contingent on a regular market being established for the stone produced and on the rates and demand remaining constant. The present is perhaps rather an unfavourable time

to start a new gem-mining industry; but otherwise, such an enterprise seems as though it would be profitable.

It may be mentioned that cut stones of A-1 quality are at present fetching from Rs. 2-8 to Rs. 3-12 a carat in India as sold to dealers.

Experiments now being conducted in making buttons, beads and other small articles of the translucent, intermediate quality seem likely to prove successful, as the first cuttings have given very attractive results.

Distance and transport rates.

It is just necessary to add a few remarks on the route to the mining area from Rawalpindi railway station. The distances are as follows :—

	Miles.
Cart road to Ganderbal	192
Ganderbal to Yonu by pony track	238
Yonu to Daso by foot path	16

The cart road to Ganderbal is a good metalled road well-graded and rises about 6,000 feet. The bridle-road from Ganderbal rises to the Zoji-La (11,300 feet) and then descends gradually to Skardu (7,700 feet), rising again slightly to 8,300 feet at the mines.

As the rates of transport all along the route are fixed for each stage it is not difficult to estimate the cost of transport to the mines from the rail, which amounts to Rs. 9-4 per maund. This is of course negligible as regards the 1st class gem-stone, but the high cost of transport enhances that of all stores and supplies necessary for the working and supervision of the mines.

LIST OF PLATES.

PRELIMINARY NOTE ON THE SRIMANGAL EARTHQUAKE OF JULY 8TH, 1918. BY CAPTAIN MURRAY STUART, I.D.F., D.SC., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 11 and 12).

I.—INTRODUCTION.

AFTER a lapse of six years, since the Burma earthquake, India experienced another severe earthquake shock on the afternoon of July 8th, 1918. The shock was felt over eastern Bengal and Assam, throughout most of Burma, and over north-east India as far west as Lahore. For the first few days the news was scanty, and it appeared that no great damage had been done, but on Thursday afternoon, July 11th, telegrams from the Srimangal area of south-west Sylhet got through, and it at once became evident that the earthquake was of considerable magnitude. Srimangal is situated in the tea-garden area, and whole valleys of tea-factories and bungalows were reported to be destroyed. Consequently I was deputed at once, by the Director of the Geological Survey of India, to proceed to the area affected, and investigate the earthquake as far as possible. I have already completed the actual touring, but am still occupied with the enquiries and correspondence connected with the investigation. Nevertheless the enquiry is sufficiently advanced for publication of a short preliminary note. The full report will be published later when all the material obtainable is at my disposal.

The earthquake occurred at about ten minutes to four, Indian Standard Time, on the afternoon of July 8th. Considering the magnitude of the shock the actual loss of life was exceedingly small, owing to the fortunate circumstance that the earthquake occurred in the afternoon when most people were awake and outside, while of those who were inside buildings, most were able to escape into the open before the buildings fell. Had the earthquake occurred at night, the loss of life, especially amongst tea-garden coolies, would have been exceedingly great, as practically all the coolie lines in the tea-gardens of the Doloi, Balisera, and Laskarpur valleys collapsed.

II.—GENERAL ACCOUNT OF THE SHOCK: ITS SUPERFICIAL ASPECTS.

As in most earthquakes of the destructive class, the shock near the earthquake centre, seems to have come with great suddenness and without any preliminary warning. The amount of damage around the epicentral area was considerable. Practically all the bungalows and leaf-houses on the tea estates in the Doloi, Balisera, and Laskarpur valleys were laid flat, those only escaping that had steel girders as a framework, and a steel girder frame for the roof. Even in these cases the brick walls between the girders were generally shattered, and in most cases thrown down. The Assam Bengal Railway suffered considerably. The sections Akhaura to Kalaura, Akhaura to Asuganj, Bhairab to Tangi, Mymensingh to Bhairab, Kalaura to Shaistaganj, Kalaura to Sylhet, and Mymensingh to Netrakona were blocked, and train service suspended. Telegraphic communication with most places in south Sylhet was interrupted, and considerable damage was done to buildings in Sylhet, Kishorganj, Brahmanbaria, Akhaura, Agartola, Maulvi Bazar and Habiganj.

The earthquake centre seems to have been in the Balisera hills, about 3½ miles south of the railway at Srimangal, and a little to the east of Dr. Mumford's bungalow at Kalighat. At the Kalighat tea-estate most of the bungalows, including the Post Office and the Club buildings, fell towards the east. At the Kajurichara estate the general direction of fall was N. N. E. At the Rajghat estate the general direction of fall was N. E. At the Puttiachara estate and Sisal Baria the general direction of fall was north, while at Srimangal and the Phulcherra estate the general direction of fall was towards the south. These directions converge approximately to a point a little to the east of Dr. Mumford's bungalow at Kalighat, and situated approximately in the gap through the hills leading eastwards to the Doloi valley. This seems to have been the main epicentre as far as it is possible to locate it, and the isoseists are found to be arranged around this point. The direction of fall becomes more confused further away from the epicentre, but the direction of fall in the Doloi valley was generally east and west, and pointing more or less generally to a point near Kalighat as the epicentre. The same applies to the Laskarpur valley.

An interesting piece of evidence of the direction in which the shock came is furnished by a resident of Rasidpur, two stations

west of Srimangal. He was standing at the side of the railway line at Rasidpur, when he heard a loud noise coming down the railway cutting which is situated between Sathgaon and Rasidpur. He concluded at first that it was the afternoon down train coming at great speed, but on looking in that direction he saw the railway line moving in waves, which travelled towards him. When the waves reached him he felt the ground shaking violently, and saw the tea factory and other buildings falling. The wave movements passed under him and he watched them recede down the line towards Shaistaganj; in other words from east to west. The railway line at this point is running approximately east and west and Rasidpur lies W. N. of Kalighat.[1]

Except near the epicentre, the earthquake shock seems to have been generally proceeded by a noise, which in most cases has been likened to the noise made by a railway train crossing an iron bridge. At the epicentre, according to Dr. Mumford, the earthquake occurred suddenly without any preliminary noise or tremors, the sudden shock, and the noise of the falling masonry and breaking of wooden beams, as the bungalow collapsed, being simultaneous.

At the Phulcherra tea estate, two miles away from the epicentre, a noise, described as a grinding noise with sharp reports, was heard as if rocks were being split and ground together; this was followed immediately by the earthquake shock.

The reported duration of the shock varies greatly in different reports, but it seems probable that the shock was little, if any, more than 20 seconds in duration, near the epicentre.

III.—THE ISOSEISMAL AREA OVER WHICH THE SHOCK WAS FELT.

Owing to the fact that there are exceedingly few brick or stone buildings over the area which was seriously affected, and to the fact that such as do exist vary greatly in nature, and strength to resist shock, it is impossible to map out isoseists according to the Rossi-Forel scale. Most of the area where the earthquake was violent enough to damage all or nearly all brick buildings, consists either of jungle-covered hills such as the Hill Tipperah area, or of low-lying land such as that seen in south Sylhet, practically all of which was under water at the date of the earthquake. Brick

[1] From information kindly collected for me by Dr. Mumford.

buildings are limited therefore almost entirely to Railway buildings, and to those in isolated places such as Sylhet, Maulvi Bazar, Habiganj, Kishorganj, Brahmanbaria, Agartala etc., and the buildings and factories of the tea estates in the valleys of south Sylhet. Consequently I have mapped isoseists on the plan adopted by R. D. Oldham in his investigation of the Great Indian Earthquake of 1897. In that investigation he found it impossible to attempt to define more than seven degrees of intensity lying within their isoseists, which he defined as follows:—

1. The first isoseist includes all places where the destruction of brick and stone buildings was practically universal.
2. The second, those places where damage to masonry or brick buildings was universal, often serious, amounting in some cases to destruction.
3. The third, those places where the earthquake was violent enough to damage all or nearly all brick buildings.
4. The fourth, those places where the earthquake was universally felt, severe enough to disturb furniture and loose objects, but not severe enough to cause damage, except in a few instances to brick buildings.
5. The fifth, those places where the earthquake was smart enough to be generally noticed, but not severe enough to cause any damage.
6. The sixth, all those places where the earthquake was only noticed by a small proportion of people who happened to be sensitive, and being seated or lying down were favourably situated for observing it.

This scale does not pretend to scientific accuracy, and it is probable that a slightly different interpretation may have been put on the intensity represented by the isoseists, to that put by Oldham. Such indeed is almost inevitable, but it has no effect on the results of the investigation.

On mapping the isoseists it became evident that they are not circular or even elliptical in shape, but are egg shaped with the narrow end pointing approximately West-north-west, indicating that the focus of the earthquake was not a point but a line, and that the intensity of the shock was greater at the east-south-east end of this line than at the west-north-west end. This would appear to mean that a slip occurred along a geological fault which runs approximately west-north-west and east-south-east through the

Balisera Hills, just to the east of Kalighat, and that the greatest intensity was under the neighbourhood of Kalighat and from there the intensity diminished in a west-north-westerly direction. No evidence of the existence of such a fault has been obtained hitherto by geological mapping, because practically the whole of its length, or at least the length along which this slip appears to have taken place, is buried and concealed by alluvium.

The two maps accompanying this report show the approximate disposition of the isoseists.

Isoseist No. 1.

The area of maximum intensity included in isoseist No. 1 is that of the Balisera valley and part of the Doloi valley. With few exceptions all brick buildings were found to be destroyed within this area. Coolie lines on the tea-estates, built mostly of sundried mud, and thatch roofs, were levelled to the ground. The usual type of planter's bungalow built of poorly burnt bricks, and very thick, exceedingly heavy, thatch roofs, also collapsed in almost every case. Tea factories and certain bungalows having steel girder frames were left standing, but the brickwork in them was either thrown down, or left in a shattered and tottering condition, in almost every case. There were one or two notable exceptions, particularly at the Bharaura Tea estate, near Srimangal, where sheltered by the side of the hills the bungalow escaped with only one or two cracks. Within this area people found it impossible to keep on their feet during the earthquake.

Isoseist No. 2.

The next isoseist, No. 2, embraces a much larger area, extending from a little west of Shahaji Bazaar, on the Assam Bengal Railway, to between Tilagaon and Kalaura Junction, on the same railway. It includes practically all the Laskarpur valley, Shamshernagar with its surrounding group of tea gardens, Maulvi Bazar and Habiganj.

Practically all the railway bridges lying within the area bounded by this isoseist were damaged by the earthquake, in many places railway embankments settled, and practically all brick buildings were damaged—many, having only mud instead of mortar between the bricks, were totally demolished. North of the railway line, with the exception of Habiganj, Maulvi Bazaar, and the continuation of the Balisera Hills north of Srimangal, the rice growing country was nearly all inundated at the time of the earthquake and conse-

quently offered little opportunity of observing the effects of the shock.

Isoseist No. 3.

Isoseist No. 3 passes approximately through Akhaura, Agartala, Brahmanbaria, Kishorganj and Sylhet. Most of the area embraced by it is either the jungle-clad hill country of Hill Tipperah, or the low-lying inundated plain of south Sylhet. Well-built buildings in this area escaped with practically no damage, but buildings built of brick and mud, or brick and very poor-quality mortar, were either left in a tottering condition, or partly thrown down. At Sylhet many houses in the bazaar were thrown down, and old *pucca* buildings that had come through the 1897 earthquake unharmed, such as the Mosque on the river front and the School, were cracked and left tottering. The Court and Deputy Commissioner's Offices, however, were only slightly cracked. Kishorganj, at first sight, appears to have suffered more than one would have expected from its position with regard to the epicentre, the Sub-divisional Officer's houses, and the houses of the First and Second Munsif being utterly destroyed, and the Jail being half demolished, but each of these was a brick and mud building, and the quality of the mud was poor, consequently their ability to withstand shock was small. The Munsif's Court at Kishorganj, which is a good brick building, escaped practically unharmed, and the railway station, another good brick building, only cracked through subsidence of the bank on which it is built, and not as the direct result of the earthquake shock. The same thing applies to Akhaura Railway station, the brick portion of which was practically demolished. In this case also the reason for the extent of the damage was the poor quality of the mortar used in its construction.

Isoseist No. 4.

The next isoseist may be split into two parts, the one passing through Comilla and nearly, but not quite, reaching to Aijal, and Silchar, while the other passes just to the east of Akyab, and from there would appear to run, in the form of an ellipse, into the Bay of Bengal in a more or less southerly direction, passing close to, but not including, Kyaukpyu. The former includes Mymensingh, Netrakona, and Cherra Poonji. A certain amount of damage to brick buildings was done in this area but this was due, either to weak construction, or to settlement of the ground on which the buildings stood. Very little is known about the area contained by the Akyab isoseist.

Both the Meteorological Observer, Akyab, and the Deputy Commissioner, Akyab, report that the earthquake shock threw down loose objects and ornaments, and also cracked buildings. The rest of the area being under the Bay of Bengal, nothing is known about it but the position occupied by isoseists Nos. 5 and 6 make it appear that its shape is elliptical with its long axis running approximately north and south. The country intervening between these two areas has been fairly well examined, and there seems no likelihood of any connection between the two.

Isoseist No. 5.

The next two isoseists are not yet definitely fixed, as all the information necessary to fix their position is not yet at my disposal, but their position can be given with fair approximation. Isoseist No. 5 contains Darjeeling, Bhagalpur, Dumka (Sonthal Pargannas), Burdwan, Monywa, Chittagong, Kyaukpyu, Bassein, and does not reach Muzaffarpur, Bankipur, Deoghur, Calcutta, Mandalay, Prome, Henzada or Rangoon. Its position is shown approximately on the map accompanying this report. Even within this area a certain number of weak buildings were cracked and occasional old houses fell. Isolated cases of objects of weak equilibrium being overturned are also reported, such as light glass flasks, in the laboratory of the Fibre Expert to the Government of Bengal, Dacca; and the instance of three out of a number of empty long glass phials being overturned in Calcutta, quoted by a correspondent in the "Statesman" of 11th July, may also be mentioned.

What appears to be a case of earthquake "shadow" or sheltering is exhibited by the area between Kyaukpyu and Bassein. Both Kyaukpyu and Bassein record a smart earthquake shock, felt distinctly by every one, whereas the Sub-Divisional Officer at Ramree reports that he was unaware that any earthquake had taken place on 8th July, and the Deputy Commissioner, Sandoway, reports only a slight shock felt by certain people, and not by everyone.

Isoseist No. 6.

The last Isoseist No. 6 contains Lucknow, Allahabad, Bilaspur, Sambalpur, False Point (Cuttack), Bassein, Rangoon, Myitkyina, Putao, etc., and its approximate position is that indicated on the map. There are certain anomalies but these may be due to separate small sympathetic shocks, and not to the main earthquake. For instance the main earthquake was felt as far as Lucknow, but it was not felt at Naini Tal, or Dehra Dun. The preliminary tremors of the

earthquake began to register on the Simla Seismograph at 15h. 55m. 20s. and the large waves at 15h. 59m. 5s. Indian Standard Time, and there was also a slight local shock, easily perceptible without instruments between two and three minutes to sixteen hours I. S. T. From the Seismogram of the Simla Seismograph, Dr. Gilbert Walker, Director-General of Observatories, recognises superposed oscillations at 15h. 57m. 45s. which he thinks indicate yielding on some fault probably within two or three hundred miles of Simla, and the time of commencement of these would seem to correspond with the shock felt in Simla.

IV.—THE ISOSEISTS IN RELATION TO THE FOCUS.

On studying the isoseists so far described certain peculiarities become evident, and these and their bearing on the nature of the focus will be discussed below. The most striking features are—

(*a*) The "egg-shaped" form of the epicentral area and of the area bounded by isoseists Nos. 2, 3 and 4.

(*b*) The closer approximation of the isoseists on the east-south-east end of the area affected by the earthquake, and their more widely separated positions on the west-north-west end.

(*c*) The concave curving of isoseists Nos. 5 and 6 towards the east, just south of Mandalay, and the apparent existence of an isolated ellipse formed by isoseist No. 4 around Akyab.

With regard to (*a*), the egg-shaped form of the Srimangal isoseismal areas seems to indicate that the original earthquake impulse proceeded from a centrum of the nature of a line or plane situated below the axis of this egg-shaped tract, rather than from one definite focus.

With regard to (*b*) it would appear that the depth of the position of the centrum was greater at the west-north-west end of this line than at the east-south-east end since the surface intensity decreases more rapidly away from the east-south-east end of the epicentral area than it does from the west-north-west end.

With regard to (*c*), the conditions imply a separate centrum situated under the Bay of Bengal west of the Akyab coast following an approximately north and south axis, rather nearer the surface than the Kalighat centrum of the Srimangal area. These would

appear to be the main and subsidiary loci of a series of separate but almost simultaneous shocks, following one another sympathetically.

V.—TIME OF THE EARTHQUAKE: RATE OF PROPAGATION.

Every investigator of Indian Earthquakes has remarked on the inaccuracy with which time is kept in different localities, and the general impossibility of obtaining accurate observations, but no earthquake investigation in India has brought this into greater prominence than the present one.

Every town has its own local time, there is generally no recognised public clock which keeps accurately this local time and consequently private clocks as a rule keep a most inaccurate time.

The difference between local time and Indian Standard Time is of course known, but few people take the trouble to check their clocks against Indian Standard Time, except very occasionally, and any unusual occurrence such as this earthquake is timed by the observer's clock, or watch, and consequently frequently differs as much as ten minutes or even more from the correct time. Instances of the use of Local Time crop up everywhere. The Newspaper reports of the earthquake published on the morning of July 9th, and on subsequent days, gave the times as:—

Calcutta—" shortly after a quarter past four."
Dacca—" about 5 o'clock "
Barisal—" at 4-30 P.M."
Chandpur—" at 4-25 P.M."
Chinsurah—" at 4-18 P.M."
Sylhet—" 4-30 P.M."
Mymensingh—" 4-30 P.M."
Balisera Valley—" 4-30 P.M."

The above are just a few instances that could be increased considerably. In no case is it stated that local time is meant, and an illustration of confusion arising from this is given by the following newspaper article:—

" SHOCK RECORDED IN CEYLON.

Madras, July 15th.

Regarding the earthquake in India which coincided witho ne in Colombo, Mr. J. P. Evans of the Colombo Observatory writes that the first vibrations recorded

reached the observatory instrument at 3-58 P.M. twenty minutes before Calcutta is said to have been affected and that all the different waves reached the seismograph practically in the same minute. The joint origin of the disturbance was close and was between Ceylon and Calcutta. It is remarkable that the shock was not felt in Ceylon and the explanation, presumably, is that the shock occurred in a fault, or faults, in a line running north and south in the bed of the sea in the Bay of Bengal and that the seat of the greatest disturbance lay further away to the north."

(*The Pioneer, July 17th, 1918.*)

As a matter of fact the first vibrations reached Colombo more than three minutes after Calcutta, the time quoted in the newspapers for Calcutta being Calcutta local time, and not Indian Standard Time; thus misleading the writer of the above article; all the other deductions in the article are unaffected by this however, and as they have a distinct bearing on this investigation I have quoted the article in full.

An investigation of the reported times of the earthquake shock reduced to Indian Standard Time, neglecting those which are very obviously wrong, yielded the following:—

Srimangal and the epicentral area	15h. 45m.
Sylhet	15h. 45m.
Silchar	15h. 45m.
Kalaura Junction	15h. 45m.
Faridpur	15h. 50m.
Barisal	15h. 53m.
Calcutta	15h. 53m.
Midnapore	15h. 53m.
False Point	15h. 55m.
Kurseong and Darjeeling	15h. 50m.
Gang-Tok	15h. 47m. or 15h. 50m.
Yatung	15h. 55m.
Aijal	15h. 47m.
Rangamatia	15h. 50m.
Kindat	15h. 50m.
Falam	15h. 53m.
Monywa	16h.
Akyab	16h.
Kyauktaw (Akyab)	15h. 45m.
Kyaukpyu	15h. 55m.
Meiktila	15h. 55m.
Sandoway	16h.
Bassein	15h. 50m.
Rangoon	15h. 55m.

The above are, in nearly every case, observations taken in local time, and then reduced to Indian Standard Time. They are therefore liable to be distinctly inaccurate particularly in the epicentral area where tea-estates are many miles from a railway station, or telegraph office, and consequently their clocks are only adjusted occasionally. The times reported from the area lying between Akyab and Rangoon do not seem quite to harmonise with the others, and Akyab, Minbya (Akyab) and Bassein each record two distinct and separate shocks with a perceptible interval between them, also Akyab itself records an intensity of 4, that is to say loose objects and ornaments were overturned and certain buildings cracked. This is confirmed by two sets of observations, the one furnished by the Deputy Commissioner of Akyab, and the other by the Meteorological Observer, Akyab. A further reference to this will be made below.

The earthquake was registered on Seismographs at Simla, Bombay, Calcutta, Kodaikanal, Dehra Dun and Colombo. The preliminary tremors and the large waves reached the Calcutta instrument at practically the same time, and the same is also the case in the Kodaikanal and Colombo records. The times of arrival of the large waves at the different Observatories, and their various distances from the point of origin are given in the following table, and, assuming the observed time of 15h. 45m. at the epicentre to be correct, the rate of travel of the long waves is calculated.

Observatory.	Distance from origin.	Time of arrival of long waves. I. S. T.	Rate of travel in miles per minute.
	Miles.	H. M. S.	
Calcutta	240	15 53	30
Dehra Dun	936	15 58 30	69
Simla	1,008	15 59 5	71·5
Bombay [1]	1,264	16 0 45	80
Kodaikanal	1,336	15 56 4	120·7
Colombo	1,432	15 58	110
Batavia (Java)	2,280	16 8	65

The above rates of travel are unsatisfactory when compared with the usual known rate of travel of the large waves in previous earth-

[1] The time given is the mean time as recorded by the different instruments. Full particulars and discussions of them will be given in the final report.

quakes. These have been found to travel usually at something approximating to 110 miles a minute. The rate varies somewhat, as a rule, with the distance travelled, but the variation is not much, and a rate of 30 miles per minute is quite incompatible with the observed rates of travel in previous earthquakes. A consideration of the above table suggests an explanation. There is one fact that is not definitely known, and that is the time of the earthquake shock at the epicentre. Also there are two other observations that present unusual features. I refer to the seismograms from Kodaikanal and Colombo, both of which start abruptly with the large waves and do not show the usual preliminary and secondary waves one would expect to find. They behave, in fact, as if the epicentre had been close and all the waves had reached the instrument at about the same instant. Because of this unusual feature, I will neglect them for the moment, and consider only the remaining records. The Calcutta seismogram is not the most suitable for using in a theoretical calculation of the time the earthquake must have occurred at the epicentre, because its distance from the epicentre is too short, and the record is confused by the fact that the preliminary waves and the long waves reached the instrument at practically the same time. I therefore turn to the next on the list, Dehra-Dun.

If a rate of 110 miles per minute is assumed as the rate at which the large waves probably travelled between the epicentre and Dehra-Dun, then it follows that the time of the earthquake shock at the epicentre must have been 15h. 50m. Indian Standard Time. Taking this time as the true time of the earthquake, and from it calculating the rates of travel to the other observatories, except Kodaikanal and Colombo, the following rates are obtained:—

Observatory.	Miles from epicentre.	Rate of travel of large waves in miles per minute.
Calcutta	240	80
Dehra Dun	936	110
Simla	1,008	119
Bombay	1,264	118
Batavia (Java)	2,280	128
	Average	111

This agrees very favourably with the results obtained in previous earthquakes, and would appear to indicate that the correct time of the earthquake at the epicentre was approximately 15h. 50m. Indian Standard Time.

The cases of Colombo and Kodaikanal then require further consideration. Taking the rate of 111 miles per minute as being approximately the established rate of travel of the long waves, then the Sismographs in these Observatories commenced to record them about five minutes earlier than they should have done, had they been recording the long waves that emanated from the Srimangal epicentre. There is no reason to suppose, that the long waves travelled from Srimangal to Kodaikanal and Colombo at vastly greater rates than they did from Srimangal to Batavia and all the other quoted observatories, and the inference seems unavoidable that the long waves recorded on the Kodaikanal and Colombo instruments came from some point nearer to them than Srimangal. This agrees with the inference drawn by Mr. Evans of the Colombo Observatory quoted in the newspaper article above.

It is, I think, extremely doubtful whether the subsidiary centrum off Akyab answers the requirements necessary to produce the Kodaikanal and Colombo seismograms, since it is sufficiently far away for the waves emanating from it to be separated into preliminary secondary and long waves by the time they reached the Kodaikanal and Colombo instruments, and it seems probable that there was still another centrum situated under the Bay of Bengal sufficiently near to Colombo and the Madras coast for all the waves to reach the Colombo, and also the Kodaikanal, instruments at the same moment, the "felt" area of which lies under the Bay and consequently was not observed. This centrum was also probably shallow, and from the recorded times, it would appear that the shock was a "sympathetic" one and not simultaneous with the Srimangal one.

In other words it seems to me most probable that the preliminary tremors from the Srimangal centrum induced, or started, a sympathetic earthquake having a centrum under the Bay of Bengal, not far from the coasts of Madras and Ceylon, and that all the waves from this centrum, together with the preliminary tremors from the Srimangal centrum reached the Colombo and similarly the Kodaikanal instrument at practically the same moment. My reason for thinking this is deduced from a consideration

of the rates of travel of the preliminary waves or tremors in the Srimangal earthquake. If it is assumed that the beginning of the shock registered at Colombo and Kodaikanal corresponds with the arrival of the preliminary waves from the Srimangal centrum, then the rates of travel of these preliminary waves to the various observatories is given in the following table :—

Observatory.	Distance from Srimangal in miles.	Time of arrival of preliminary waves.	Rate of travel in miles per minute.
		H. M. S.	
Dehra Dun	936	15 54 15	220
Simla	1,008	15 55 20	188
Bombay	1,264	15 56 4	·203
Kodaikanal	1,336	15 56 4	220
Colombo	1,432	15 58 0	240
Batavia	2,280	15 58 54	256

It will be seen that the rates to Colombo and Kodaikanal agree very closely with the rates to the other observatories, and therefore it would seem that a separate and distinct earthquake shock must have occurred under the Bay of Bengal, that it was a sympathetic one and occurred when the preliminary tremors from the Srimangal earthquake reached its centrum, and that from thence its own tremors and waves went on together with the preliminary tremors of the Srimangal earthquake to Colombo and Kodaikanal, giving a confused record in both cases. The same reasoning seems to apply to the Akyab centrum, that a sympathetic shock occurred there and not a simultaneous one. The observed times in this case are unchecked by any instrument records but the times recorded by the various observers, south of Akyab and Monywa are earlier than would be expected if they recorded the arrival of the long waves from the Srimangal centrum and later than would be expected if they recorded the waves caused by a shock occurring in the Akyab centrum simultaneously with the Srimangal shock—*i.e.*, at 15h. 50m. Indian Standard Time. It again appears as if the preliminary waves from the Srimangal centrum reached the Akyab area and there started a sympathetic shock, the waves from which reached Burma earlier than the long waves from the Srimangal centrum did.

These sympathetic shocks will be discussed at greater length in the final report.

VI.—FORE-SHOCKS AND AFTERSHOCKS.

A number of aftershocks occurred after the main shock on 8th July, but discussion of them will be reserved for the final report. In addition to these there is evidence of at least two fore-shocks, one between 2 and 3 A.M. on the morning of 2nd July, and the second between midnight and 1 A.M. on the morning of 7th July.

These shocks were only felt locally in the immediate neighbourhood of the epicentre and did not register on the Calcutta seismograph; that of 2nd July was felt both at Kalighat and Phulcherra while the one on the morning of 7th only woke up people at Kalighat. Both of these fore-shocks were accompanied by a noise likened by Dr. Mumford to the breaking of a wooden beam in the case of the first one, and to a dull thumping noise in the case of the second one.

VII.—DEPTH OF THE FOCUS.

In attempting to determine, as far as possible the depth below the surface at which the focus lay, only one method, of the many proposed by different authors, can be applied in the present case, and that is the method proposed by Major C. E. Dutton.[1] This method depends upon the assumption that, in a uniform medium, the intensity varies as the square of the distance from the origin, and it is shown that the variation of *surface* intensity along a horizontal line drawn from the epicentre is most rapid at a particular point which depends upon the depth of the focus only; a point also where the intensity must be $\frac{3}{4}$ of the maximum intensity at the epicentre. The relation between the two is exhibited by the formula $X = Q \tan 30°$ where X is the horizontal distance of the place from the epicentre and Q the depth of the focus. If X is known, then $Q = X\sqrt{3}$.

On applying this formula to the present earthquake by making a section across the epicentral tract near Srimangal at right angles to its long axis, it appears that the intensity declines, or varies, most rapidly at points situated about 5 miles from the epicentral line. The focus, therefore, under Balisera valley must lie at a depth below the surface of about $5\sqrt{3}$ miles, *i.e.*, between 8 and 9 miles.

[1] "Earthquake in the light of the new seismology," Chapter IX, (1904).

Owing to the fact that buildings are few and scarce over the epicentral area, it is impossible to fix the point where the surface intensity declines most rapidly, with any degree of accuracy, and the above estimate of the depth of the focus under the Balisera valley is, at best, only vague; nevertheless it is the nearest approximation that can be made. At the west-north-west end of the epicentral area the observations are too few to enable any calculation to be made, most of the country being low lying rice fields which at the time of the earthquake were inundated owing to the unusually heavy monsoon.

Owing to the inaccuracy of practically all the observations in respect of the time at which the earthquake occurred at different places, it is impossible to calculate the depth of the focus by the method proposed by Dr. Aug. Schmidt based on the observed rates of travel.[1] The observed times in different places quoted in the foregoing pages, are obviously inaccurate and unreliable. The various railways have very kindly furnished me with the times the earthquake was recorded from the railway stations, but unfortunately these records also contain so many obvious inaccuracies that they are useless for the purpose required. Consequently the construction of a hodograph is impossible.

VIII.—SURFACE EFFECTS.

No changes of contour and drainage, or formation of fault cliffs, have been recorded as the result of mass movements of the solid rock from below upwards, such as occurred in the Assam Earthquake of 1897 or the Japanese Earthquake of 1891, but many instances of slips along the sides of steep slopes, and subsidence along the banks of rivers and streams, occurred, due to the earthquake vibrations loosening material sufficiently for the force of gravity to make it slip in a downwards direction. Generally, throughout the area enclosed in Isoseists No. 1 and No. 2, the sides of steep hills and railway cuttings have suffered small slips. The railway embankment leading up to the Fenchuganj bridge on the Kalaura-Sylhet section settled considerably, and in places left the railway track hanging in air; many buildings such as the railway station at Kishorganj, and buildings at Netrakona were cracked owing to the settlement of the ground on which they are built. The railway station well at Gourigram sank below ground level,

[1] Jahresheft, Ver. f. vaterl. Naturk. in Wurttemberg, XLIV p. 227, (1890).

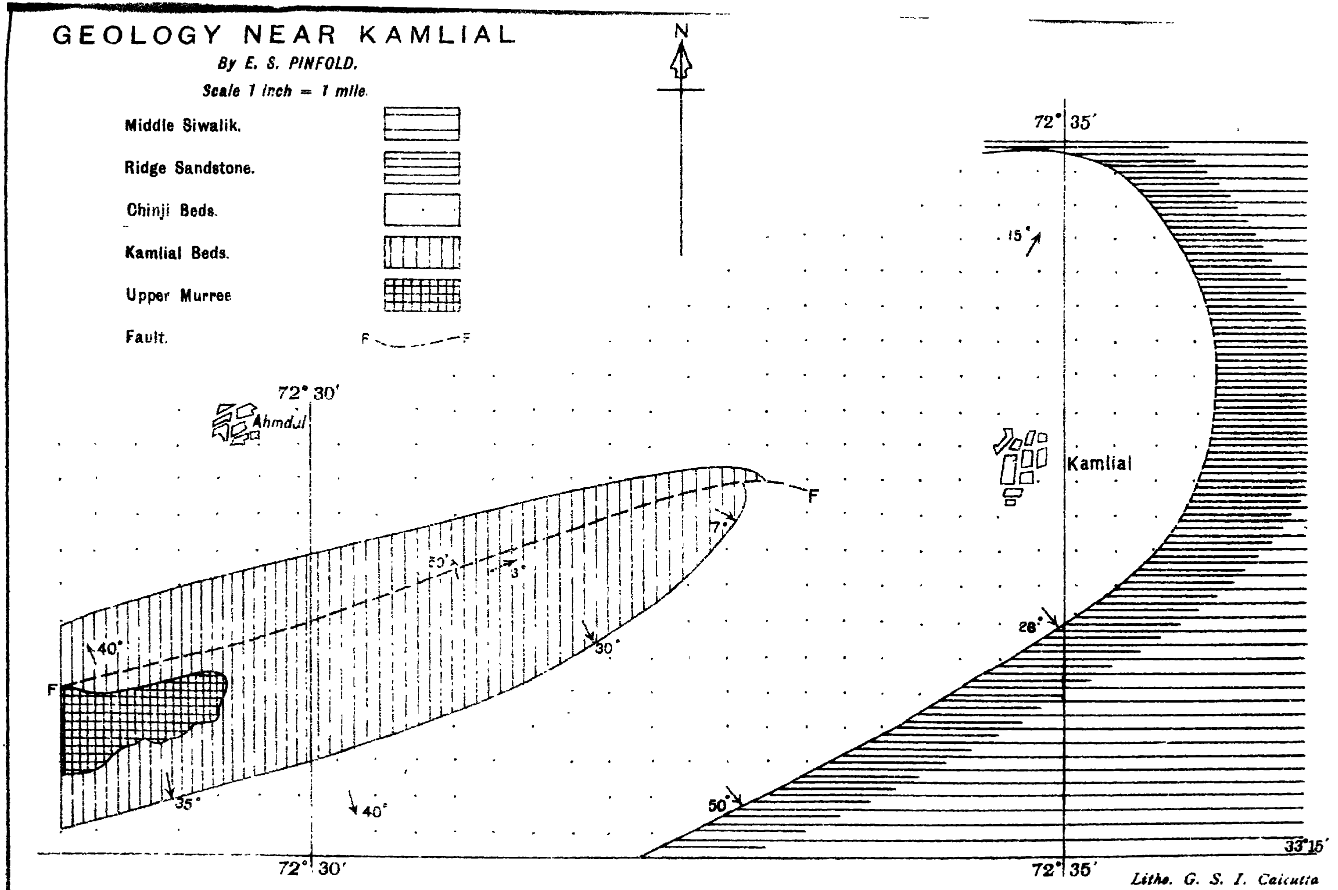
and many well-platforms sank several inches, particularly at Netrakona. The most striking surface effect was perhaps the pouring out of water, sand and mud, from fissures and vents in the ground. The theory of this phenomenon has been fully discussed by Oldham in *Memoirs Geological Survey of India*, Vol. XXIX, pages 85-111, and it is only necessary here to mention the places where the phenomenon was common. Cases of sand and water issuing from the ground are common in the epicentral area, and the instance may be quoted of the Phulcherra Tea Estate where simultaneously with the collapse of the bungalow, numerous vents occurred on the tennis-court from which water and sand spouted up to a height of several feet. When these subsided the tennis court was found to have settled irregularly so that instead of being level it was a series of mounds and hollows.

Similar cases of the spouting out of sand and water are reported from Sylhet, Agartala, Comilla, Kishorganj and Netrakona. The phenomenon seems to have been exceedingly common between Gourigram and both Netrakona and Kishorganj, the borrow pits by the side of the railway line being frequently filled up with sand and mud that had issued through vents in this way; some of the wells at Netrakona filled up with sand and water and overflowed.

Cracks due to subsidence of the alluvium were not infrequent, but these were almost invariably parallel to a road, river, or embankment. In addition to the above cases occurred of movement and bending of both tramway and, railway lines. The tramway lines in both the Balisera and Doloi valleys were in places moved a distance of several feet laterally from their alignment, and at Gourigram where there is a triangle instead of a turntable to enable railway engines to turn around, the two sides of the triangle were considerably bent, one rail being found to have a curvature equivalent to a radius of 30 feet. The base of the triangle which was facing the epicentre, and approximately at right angles to the direction in which the waves came, was not affected. Numerous cases are recorded also of movement having occurred in the piers and abutments of railway bridges, particularly in those lying along the direction in which the earthquake shock travelled.

LIST OF PLATES.

PLATE 11.—Map showing the epicentral area and Isoseists Nos. 1, 2, 3 and 4.
PLATE 12—Map of India showing area over which the earthquake was felt.

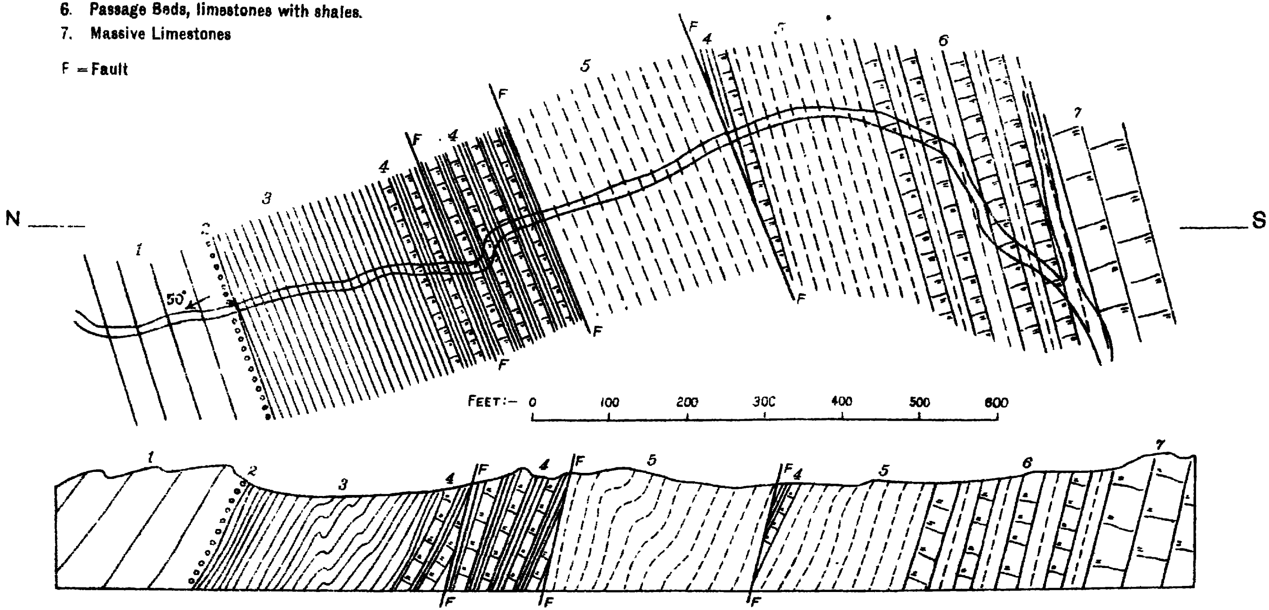

GEOLOGY NEAR KAMLIAL
By E. S. PINFOLD.
Scale 1 inch = 1 mile.
Middle Siwalik.
Ridge Sandstone.
Chinji Beds.
Kamlial Beds.
Upper Murree
Fault.
F
F
N
72° 30′
72° 35′
Ahmdal
Kamlial
15°
28°
50°
7°
3°
30°
40°
35°
40°
33°15′
Litho. G. S. I. Calcutta

PLAN & SECTION IN STREAM EAST OF CHHARAT VILLAGE

By E. S. PINFOLD.

1. Fatahjang Zone passing up into Murree Beds.
2. Basal Conglomerate.
3. Nummulite Shales } Upper Chharat Stage
4. Limestones & Shales } Upper Chharat Stage
5. Variegated Shales   Lower Chharat Stage.
6. Passage Beds, limestones with shales.
7. Massive Limestones

F = Fault



Litho. G. S. I. Calcutta

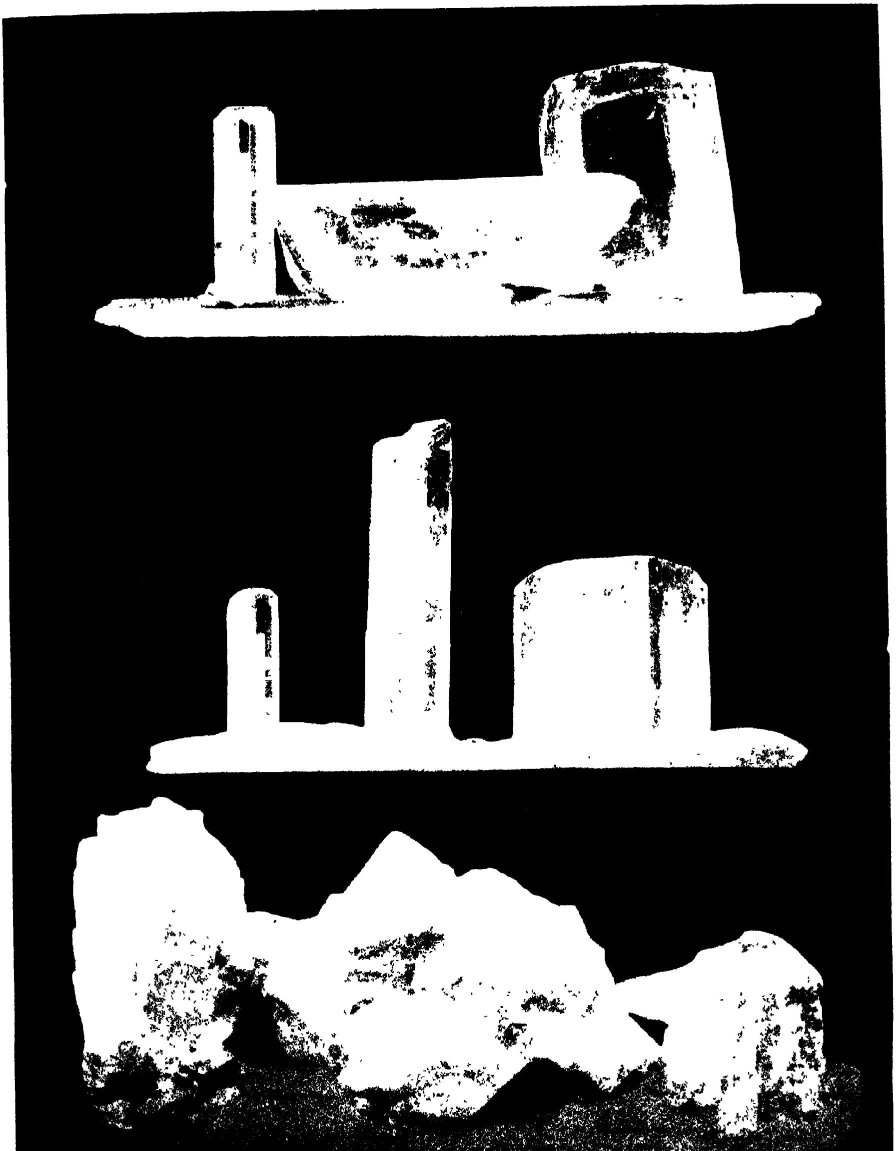
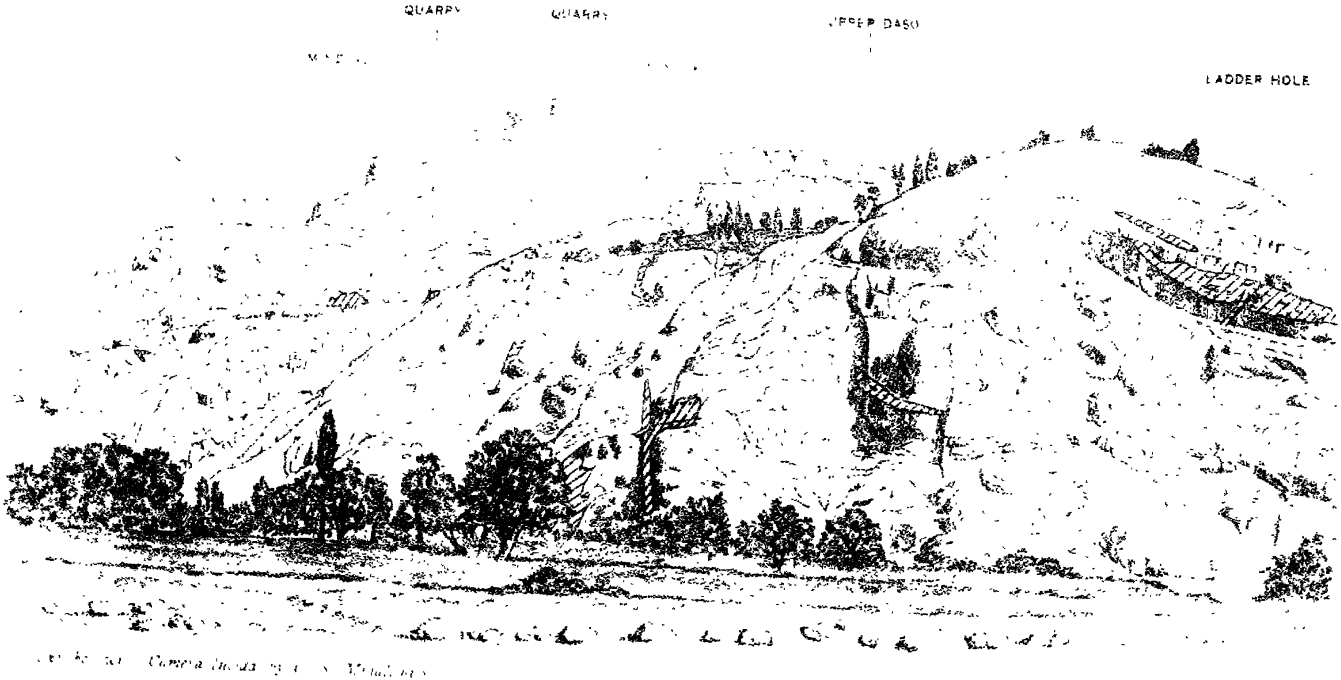


Photo by C. S. Middlemiss. G. S. I. Calcutta.

AQUAMARINE CRYSTALS.

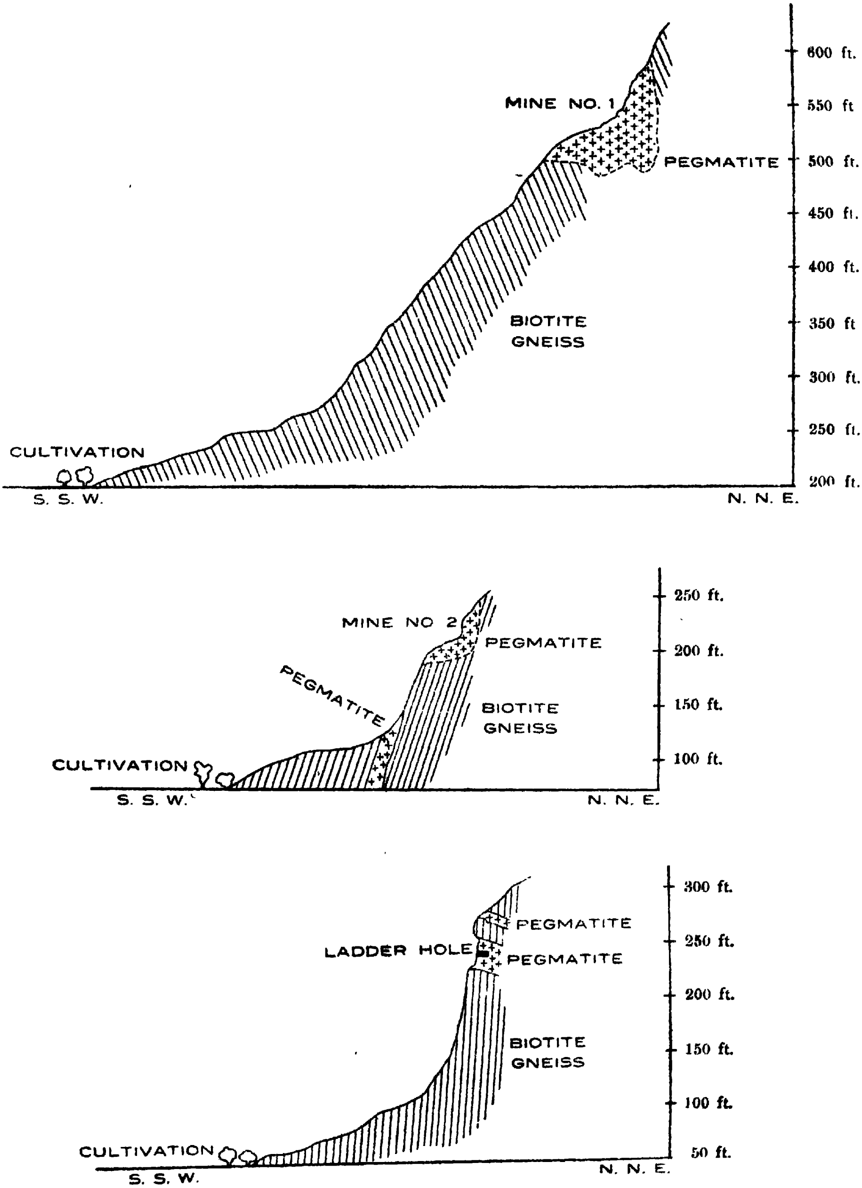
Photo. by C. S. Middlemiss.

MINE No. 1.



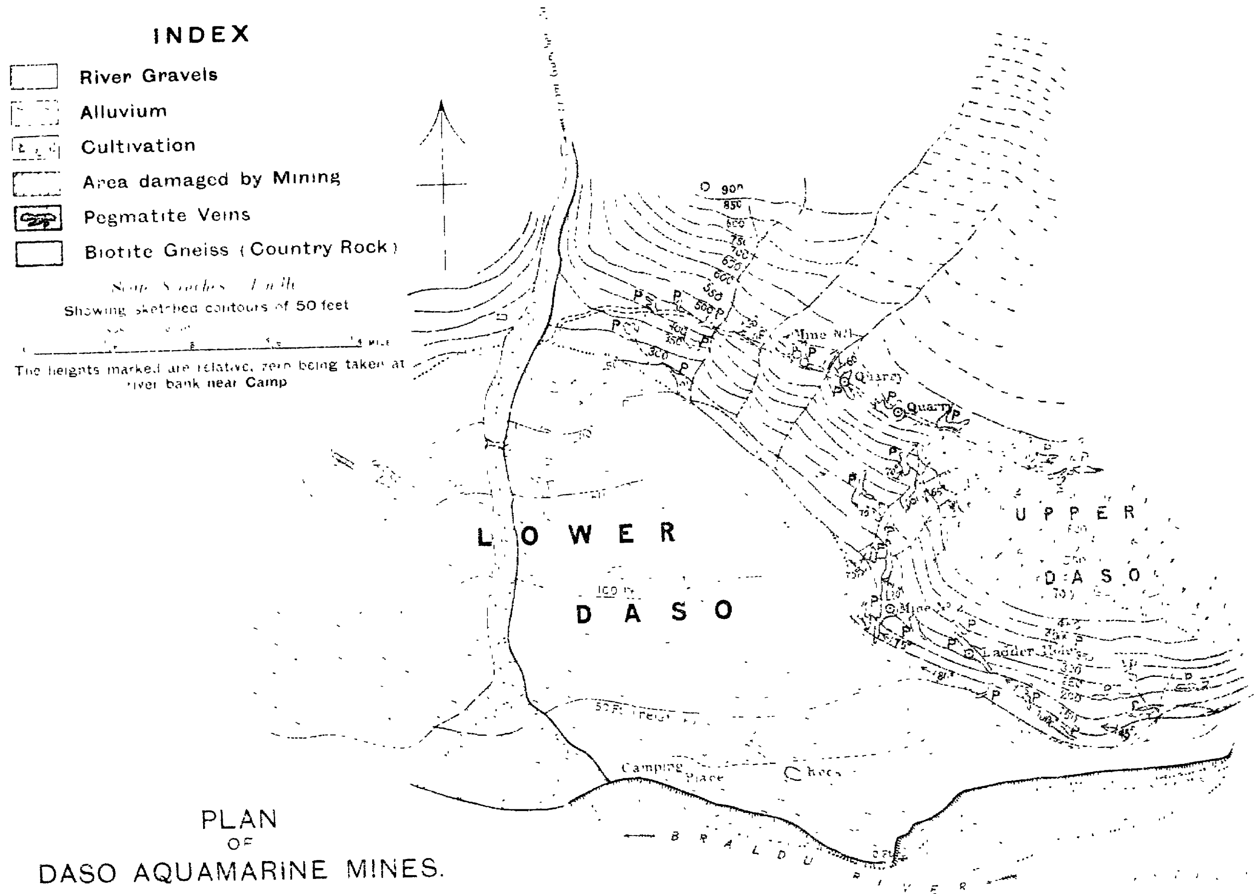
DASO AQUAMARINE MINES, VIEW FROM LOWER DASO

Records, Vol. XLIX, Pl. 9.



HORIZONTAL AND VERTICAL SCALES THE SAME.

Sections by C. S. Middlemiss. *G. S. I. Calcutta.*



PLAN
OF
DASO AQUAMARINE MINES.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1919. [March

POSSIBLE OCCURRENCE OF PETROLEUM IN JAMMU PROVINCE: PRELIMINARY NOTE ON THE NÁR-BUDHÁN DOME OF KOTLI TEHSIL IN THE PUNCH VALLEY.

BY C. S. MIDDLEMISS, C.I.E., B.A., F.G.S., F.A.S.B., *Superintendent, Mineral Survey of Kashmir.* (With Plates 13 to 16.)

I.—INTRODUCTION.

Investigation incomplete.

ALTHOUGH the issuing of preliminary reports is often objectionable, the matter discussed in this note, namely the possibility of there being a petroleum supply in the State, is of such importance that I have not hesitated to do so in this instance. To avoid giving a false impression, let me say at once that so far I have no surface traces of actual oil to record, though these may yet be found on further detailed search. Briefly, what I have discovered is a natural reservoir of the best type, suitable for the underground concentration and storage of oil; and this natural reservoir or 'dome' occurs in rocks of similar age and identical structure and lithological character with those of the neighbouring oil region of the Rawalpindi plateau. The precise significance of this discovery, from the point of view of the chances of the reservoir now containing oil, will be fully discussed later in this paper.

That this account must necessarily be a preliminary one is evident from the fact that the examination of the whole province is still incomplete; a drawback that is unavoidable in view of the

large extent of country involved, which renders the exploration of the whole of it a matter of several cold-weather seasons rather than of the one or two months that I have so far been able to devote to it.

Although incomplete it is self-contained and trustworthy.

But, although incomplete, this account will set forth in detail a number of facts of special interest, and lay a foundation so-to-speak for future progress. All subsequent work, I trust, will be of the nature of additions rather than of extensive alterations. In other words this preliminary account may be regarded as a first and most essential chapter or instalment of a subject, that is naturally of some magnitude, to which other chapters will be added as the area examined becomes more comprehensive. So far as it goes this first instalment is self-contained and trustworthy.

This report describes a definite field-season's work.

A second reason for putting this note on record now is that it describes and summarises a definite field-season's work. It is always desirable in the interest of the writer, if not of the reader, to take stock of the results attained at the end of any work period, so as the better to appreciate what still remains to be done and to lay plans accordingly. A subject like the investigation of petroleum is particularly suitable to this treatment because of its concrete, circumscribed nature, whereby it ordinarily does not overlap any other mineral enquiry.

Ventilation of the subject necessary to arouse general interest.

Lastly it is desirable as early as possible to ventilate the subject, which is entirely new in Kashmir. Hence an immediate statement of results may be valuable in arousing an attitude of sympathetic interest among other departments of the State towards the subject of oil, and so lead to a general search for the occurrence of seepages of oil, gas, and hot or other mineral springs, all of which phenomena are so many surface signs that frequently accompany and disclose the presence of oil below.

Value of the results.

Whatever be the immediate outcome of this report as regards a policy of test operations, the detailed facts of structure and composition of the rocks of the area, accompanied by large-scale plans, sections, views and photographs herewith recorded must always have their own proper value as being exact morphological data, without which no intelligent

developmental operations of any kind could be contemplated in the future. Incidentally it may be remarked that the quantitative, graphical delineation to scale of these results has only now for the first time been rendered possible by the new contoured 1″=1 mile topographical maps of the area, recently issued by the Survey of India.

Economic importance of petroleum.

It would be superfluous in these days to urge the claim that petroleum has to special consideration. Its well-known ability to yield liquid fuel, lubricating oil, illuminating oil (kerosene) and the lighter forms of petroleum spirit (petrol) sufficiently summarises its manifold uses. It may, however, be remarked that in one respect the discovery of oil in this part of India would be specially advantageous. For, whereas the other chief oil-producing parts of India, namely Burma and Assam, either have coal of their own or easy access to supplies of it by sea or river transport, the north-west portions of India, on the other hand, possess little or nothing in the way of solid mineral fuel. Hence for this purpose alone—namely as liquid fuel for locomotives on the railway and for other stationary oil engines now rapidly coming into vogue in this country—the discovery of stores of oil would be an inestimable boon; although this use for oil is less remunerative than others.

Demand constantly increasing.

It may also be noted that in India, as indeed in all parts of the world, the universal demand for petroleum products is steadily rising, in consequence of their use in internal combustion engines for motor transport by road, and in light-weight engines for all forms of aircraft.

The present and immediate future may be regarded industrially as the age of oil as contrasted with the age of coal, which latter having reached its maximum of output in many countries, must soon begin to decline. The special conditions engendered by the war have further increased the intrinsic importance of new oil discoveries, whether here in India or elsewhere, and clearly point to the desirability of intensive exploitation of all possible sources.

Oil exploration dependent on exact geological data.

I may close this introductory chapter by a few remarks on the scientific search for petroleum. Oil exploration and exploitation, in the modern sense, as a serious industrial enterprise, is only of very recent growth, dating in fact from the

year 1859, when the first oil well was drilled; since which date the extraction of oil has proceeded by leaps and bounds. But, even so, the locating of a site for an oil-field was for a long time almost entirely accidental, fortuitous or unregulated. It is only within the last decade or so that such investigations have definitely taken rank along with those of other mineral products as a branch of exact science, and in particular as a branch of geological science. It is significant that the principal oil companies in India have each now had for some years a group of fully qualified geologists on their staff who are continuously engaged in exploring all the conditions under which new oil-fields may be located and old ones extended. Of still more significance is the recent progress in the scientific method of oil exploration made in America since the war began; as the following extract from *Mineral Industry* during 1916, Vol. XXV, pp. 538-539, will make evident:—

> 'In 1916, between 450 and 500 men were employed in geological work in Mid-Continent oil fields, as against four or five in 1913. There are, I should judge, 250 geologists in these fields and the other men are assistants, instrument men and rod men, nearly all of whom have had geologic and engineering training but have not had enough experience to be classed as geologists though they are generally known as such.
>
> The growth of geology is due to the fact that in the past 4 years, 1913, 1914, 1915, and 1916, 32 out of 45 pools or 71 per cent. of the pools discovered have been the result of geological work.
>
> The success in average "wildcatting" without geologic guidance, is one test in one hundred and fifty. Geologic work has reduced this to one in three.'

The above facts are eloquent as advocating the urgency for systematic examination of all possible areas for petroleum in the light of the geological structure and history of each area. Oil-fields undoubtedly have in many cases in the past been found by random search, as one might look indiscriminately for buried treasure, but at the expense of untold amounts of misdirected and wasted energy. One is justified in expecting much more of certainty and economy from a rationally directed and scientifically infused search.

It is hoped that the following account of such an investigation, based on accurate survey work, may lead to proportionately valuable results.

II.—PRELIMINARY CONSIDERATIONS AND INVESTIGATION.

Statement of already known facts.

At the outset of any enquiry regarding the possibility of oil occurring in Jammu Province, we have the following known facts of special and general application :—

The area is contiguous to a known oil area on the north-west.

In the first place Jammu Province, along the valley of the Jhelum, is contiguous to or marches with the Rawalpindi district, where oil has long been known to be present, and where efforts to obtain it in marketable quantities, after many failures, have recently been crowned with success by the discovery of the Khaur oil-field near Pindigheb. Although as much as half a million gallons of oil were extracted by the Attock Oil Company, Ld., during 1915 and 1916 (see *Rec. Geol. Surv. of Ind.*, Vol. XLVIII, Pt. 2, p. 52) from this field, it is (owing to various circumstances) still only in the experimental stage, though enough is known to show it to be a promising field. A recent paper read by Mr. E. S. Pinfold, Geologist to the Indo-Burma Petroleum Company, Ld., at the Indian Science Congress held at Lahore in January 1918, has summarised the data available regarding the history of petroleum in the Punjab.[1] Some notes on this will be found in the Appendix to this account, and numerous references to the geological structure subsisting at Khaur will follow in the next section of this report. For permission to reproduce these I am indebted to the kindness of the Indo-Burma and Attock Oil Companies.

The area is contiguous to a gas locality on the south-east.

Secondly, in the other direction, Jammu Province marches with Kangra district, where the long-known gas seepage of Jawalamukhi is an outward sign of oil beneath the surface, although this area has not yet been proved.

It forms part of a well-known petroliferous belt.

Thirdly, the whole of the belt of stratified rocks in Jammu, embraces a section of the Sub-Himalayan rocks of Tertiary age from Eocene upwards, which are identical in composition, age and lithological characters with those of the petroliferous

[1] *J. & P. A. S. B.*, XIV, No. 6, pp. clxxiii—clxxxiv, (1918).

series in the neighbouring Rawalpindi district. They are also identical in age with, but differ in some particulars lithologically from, the petroliferous series in Assam and in Burma and also in the newly discovered fields in Persia. In fact they form with these known petroleum-bearing areas what is really one continuous but intricately winding belt of deposits belonging to one comprehensive geological epoch, that stretches from Persia on the one hand to the extreme south of Burma on the other. It is also equally true that in general characters and in age these rocks exposed in Jammu agree with those of a great proportion of the more distant successful oil-fields of the world, notably with those of California, Peru, Russia, Rumania, Galicia and Sumatra.

It is thus clear that there exists a strong presumption for suspecting that the low foot-hills of Jammu, lying within and as part of one of the petroliferous belts of the world, might very well yield oil over some parts of their area. It was mainly from a consideration of the above general facts that an examination with this object seemed to me imperative, and sanction to undertake it was accordingly obtained.

Preparatory visit to Khaur oil-field.

The suspicion that the rock formations of the Jammu foot-hills might contain hidden oil-fields arising from the facts just enumerated, led me to examine what was already known and recorded of the geological structure and stratigraphy of the Jammu region and to compare it specifically with that of the Rawalpindi area. In this comparative examination I received much assistance from Mr. Pinfold, who during early February, with the courteous permission of his company, was kind enough personally to conduct me over the Khaur and Dhulian fields near Pindigheb and to show me everything there was to be seen without reservation.

Nár-Budhán dome a replica of Khaur.

After this preparatory work at Khaur I proceeded straight to what I anticipated to be a somewhat similar region (from a structural and stratigraphical standpoint) in the lower reaches of the Punch R. in Mirpur and Kotli tehsils of Jammu. After some weeks of search I was rewarded by the discovery of what I have named the Nār-Budhān 'dome' (after the two villages of those names on the left bank of the Punch R. lying 10 miles south-west of Kotli town and 15 miles north of Mirpur). This dome I found to be strikingly similar to the Khaur dome from a large number of most important

points of view, and it is on the basis of this identity that further investigation and consultation is proposed and, if finally found advisable, the undertaking of test-drilling.

In the next section I shall describe the morphology of the Nár-Budhán dome, comparing it in detail with its prototype the Khaur dome as I proceed.

III.—THE NÁR-BUDHÁN DOME.

(a) Stratigraphical Features.

Two anticlinal flexures with bands of 'Murree' rocks.

If reference is made to the maps of Medlicott, Lydekker, and Wynne, which represent, on the small scale of 1″=8 miles, the early pioneer Geological Survey work done on the Sub-Himalayan rocks of Jammu and the Rawalpindi plateau (*Rec. Geol. Surv. of Ind.*, Vol. IX, Pt. 2, p. 49, 1876, and Vol. X, Pt. 3, p. 107, 1877), we may observe, standing out prominently in the structure of the area, two anticlinal flexures, which cross the Punch R. in a north-west—south-east direction, on each side of, and parallel to, the troughlike synclinal fold of the Sensar (Sahnsar) dun. Coincident with the axes of the flexures, and obviously forming the cores of them, there will be found to be marked on those maps two extended narrow bands of rocks of "Murree" age which die out in both directions after continuing in each case for some 25 miles.

Although the so-mapped cores of Murree rocks in the anticlinal flexures die out as stated, the flexures themselves are marked as continuing (with a sharp, right-angled change of direction at the Jhelum river) into connection with the area round Khaur, whilst further isolated patches and bands of so-called Murree rocks appear discontinuously along their course. The flexures also continue in a south-easterly direction from the Punch R. into areas outside the limits of our present enquiry.

The northern band.

The northern of the flexures with its core of Murree rocks I examined by a number of cross traverses, between Melian and Barali, but everywhere I found this strip to be an exceedingly narrow, compressed, or tight, anticline with vertical or steep dips along the line of the axis. It was also seen that the rocks exposed in the core of the fold were not very like normal Murree beds (which are generally of a deep

and sometimes brilliant purple, or purple "shot" with green colour), but instead were more like those peculiar to what will presently be referred to as the Chinji zone, of Lower Siwalik age. There was but a trace of these rocks seen in that anticline, hardly sufficient to map with certainty in any case. Such an anticline, it is generally admitted, would be unfavourable for the collection and retention of oil, so I passed on to the examination of the south anticline.

The southern band.

This I traversed across at a few places between Nawan and the Punch R. It appeared to be of more promise, as the band of Murrees, or Chinjis was wider, with less steeply dipping limbs to the anticline, and the bright, brick-red shales and hardened clays intercalated with pale tinted sandstones had a considerable development, especially in the stream-bed north-west of Nawan.

Expansion in the Punch R.

But it was at the point where this southern band crosses the Punch R. that I was agreeably surprised to find the mapping of the earlier observers at fault, for the band instead of remaining of the ordinary width of about ½ mile was found to become expanded out to a width of about 3 miles. With this expansion went a lowering of the inclination of the beds and the production of an elongated dome-structure with longitudinal faulting along the major axis.

This constitutes the core of the Nár-Budhán dome, the main subject of this report.

General shape of the Nár-Budhán dome and its position in the structure of the country round.

The general shape and extension of this will best be gathered from the geologically coloured 1″=1 mile map (Pl. 13). As regards the rest of the area just referred to, where the long narrow extension of the two anticlines was examined by me, the essential features presented by them may best be appreciated (sufficiently at least for present purposes) by a study of the horizontal sections. These sections have been constructed on the natural scale (horizontal and vertical being equal) and are four times that of the 1″=1 mile map, Pl. m 13. The outline of the sections has been plotted from the contoured topographical sheets, and the geological details from actual traverses with compass-clinometer. It may thus be accepted that they represent not only in general outline but also in detail, the true amounts and curvatures of the earth folds, and, what is of great

importance in all cases where drilling may be required, they enable us to calculate the thickness of the strata with some approach to accuracy. It would be out of place here to describe these sections in any further detail, but a reference to them was necessary in order to obtain a clear grasp of the position and lie of the Nár-Budhán dome with reference to the rest of the surrounding formations. Horizontal Section No. 1, Pl. 16, is drawn from south-west to north-east roughly through the villages of Sahália, Amb, Bihári, Khaira, Sensa (Sahnsa), Bharuhian, Kaini and Panjera to the 4,937 feet peak, all these places being on the north-west or right bank of the Punch R. Horizontal Section No. 2, Pl. 16, is drawn also south-west—north-east, keeping to the left bank and passing through or near the villages Pàlák, Kanora, Rajdhani, Nár-Budhán, Tharochi, Baráli, Kurti and Ishkiáli.

Formations represented. The formations represented in the Nár-Budhán dome area are as follows :—

Upper beds (*Middle Siwalik*).—Soft sandstones and pale-coloured shales, weathering into massive mural cliffs. Thickness exposed in the dome area immediately surrounding the core of lower beds, about 4,000 feet.

Lower beds (*Lower Siwalik*).—Soft sandstones with scattered foreign pebble layers and with prominent brick-red shales and harder pseudo-conglomerate beds, the last being especially developed below at the actual crest of the dome. Thickness, so far as visible down to the lowest exposed beds about 3,300 feet.

Whilst the upper series undoubtedly belongs to the Siwalik sandstones, as so named by the old observers, and probably to the Middle Siwalik as now defined, the lower beds characterised by the deep-coloured shales and other features mentioned above, were classified by the earlier observers as belonging to the Murree group. A more recent study of a similar series of rocks in the neighbouring areas of the Punjab to the west of Kashmir by the light of their vertebrate fossil remains has been made by Dr. G. Pilgrim of the Geological Survey of India and by Mr. E. S. Pinfold (see especially *Rec. Geol. Surv. Ind.*, Vol. XLIII, Pt. 4, pp. 264—326; Vol. XLVIII, Pt. 2, pp. 98—101). These researches make it necessary that the whole of the series with the brick-red shales and the harder beds below, amounting to about 4,000 feet in the Khaur

area, should be elevated altogether out of the Murree group (which is typically a formation barren of anything but a few obscure plan remains). Those red beds have thus come to be known as the Chinji stage (from Chinji in the Salt Range) and the harder underlying layers as the Kamlial beds (from the village of that name in the Rawalpindi plateau, a few miles east of Khaur) and in Pilgrim's classification they represent stages in the Lower Siwalik.

Comparison of the Nár-Budhán and Khaur horizons.

From the study of the Nár-Budhán section as far as it has gone, it seems practically certain that the series there exposed is a more or less exact reproduction of the Khaur and neighbouring sections, and therefore that the 3,000 feet or so of strata with brick-red shales in the Nár-Budhán dome are identical with the Chinji beds of Khaur and that they are followed downwards by beds extremely like the Kamlials. The points of analogy between the series in the compared areas are succinctly as follows :—

Firstly, reckoned both from a southerly direction and also from the north, the rocks constituting the Nár-Budhán dome show every sign of lying in one conformable sequence down from the coarse river-boulder conglomerate of the Upper Siwaliks, which we may take as a rough datum line for present purposes. Although there is one interruption by faulting in the southern section near Rajdhani and Bihári, in the northern section, the series, as far as the Siwalik conglomerate in the neighbourhood of Kotli town, appears intact and undisturbed by anything except regular flexuring. The same continuous sequence is manifested by the rocks of the Khaur dome in their relation to the overlying series as far as the Siwalik conglomerate of the Sohán R.

Secondly, in the Nár-Budhán area, all the series of soft sandstones or sand-rock and the interbedded shales in the upper portion of the section, which lie thus in conformable infra-position as regards the Siwalik conglomerate, are solely characterised by ochre-tinted, grey, or 'khaki' shales or hardened clays, with perhaps a few of a brownish tint, down to the central portion of the dome, where the bright or deep brick-red shales commence. The same is true in the section south of Khaur from the Sohán R. down in the sequence to the 'ridge' group of Pinfold, which marks the beginning of the similarly red-tinted Chinji group.

Thirdly, the sandstones interbedded with the bright red tinted shales in both the Nár-Budhán and Khaur areas are marked by

the prevalence of sparsely distributed pebbles of old foreign rocks, quartzites, etc. These are not large nor numerous, but can easily be found when the rocks have been disintegrated by surface weathering.

Fourthly, the same beds in both areas are eminently characterised by the presence of hardened layers of the well-known pseudo-conglomerate. These increase downwards in the section, and in combination with sandstone layers give rise finally to the more massive-weathering sheets of rock which partially cover in the crest of the dome in both cases. A small but perhaps suggestive feature in the Nár-Budhán area is that these lower sheets group themselves into two main scarps, the lower of which is particularly precipitous and cliff-like, so as to stand out prominently in the topography and to be distinctly represented on the map, a feature which is equally prominently noticeable in the Khaur ellipse and gives to it its characteristic contours as seen from any point in the neighbourhood.

Fifthly, as regards fossil contents, my examination of the Nár-Budhán area has been too restricted at present to yield much positive evidence. Vertebrate bones were, however, found near Nár at a position of from 100—200 feet above the top horizon of the red beds, and among these has been identified a molar tooth of *Mastodon*, probably *M. latidens*. Other fragmentary and undetermined bones were found at one point actually in the red beds. So far as the above evidence goes it suggests a Middle Siwalik age for the sandstone overlying the red series, and though there is nothing in my collection so far to prove the age of my red beds they cannot very well be placed with the Murree series and hence must come between them and the Middle Siwalik.

Sixthly, as regards thickness calculated from the scale sections my series above the red beds up to the base of the Siwalik conglomerate totals 12,400 feet and that of the red beds down to the lowest visible bed at the crest of the dome 3,300 feet. A comparison of these thicknesses with those of the neighbouring Rawalpindi plateau cannot be made in detail as the latter vary much and are only approximate. Roughly they correspond sufficiently well.

The practical positive inferences that I feel myself entitled to draw from the above correlation of the two areas are that the 3,000 feet or so of red beds forming the core of the Nár-Budhán dome are the undoubted equivalents of all or part of the Chinji

stage as exhibited at Khaur, whilst I think it more than likely that the crest-sandstone with its pseudo-conglomerate layers that sheet in much of the Nár-Budhán dome may also with considerable confidence be correlated with the crest-sandstone, or lower Kamliál bed of Khaur.

This places the horizon of the crest beds in my area either within measurable distance of that at Khaur or in actual agreement with it. In any case it is almost certainly lower in the series than the crest beds of the Dhulián field. The significance of this will be referred to again when I consider the prospects of oil being retained in the Nár-Budhán dome.

(b) Structural Features.

Summary of data furnished by the 4″=1 mile map.

For details concerning the physical conformation of the dome the enlarged map on a scale of 4″=1 mile, Pl. 14 and the four horizontal sections, A, B, C, and X, Plate 16, must be consulted in addition to the 1″=1 mile general map of the area, Pl. 13. It is hardly necessary to put down here all the numerous items of information concerning the dips, anticlinal axes and subsidiary folds that can be found plainly shown on the enlarged map and sections (the maps and sections should always accompany this report as they are the most important part of it). I will endeavour, however, to summarise these scattered items in a few words so as to bring out their more salient features, or those that are of chief importance in elucidating the structure of the dome.

Size of dome-area effective area.

It is first of all clear that the full area of the dome, as contrasted with the area of any future oil-field that may become possible, is very large. I am indebted to Dr. E. H. Pascoe, Superintendent of the Geological Survey of India, for drawing my attention to the special significance of this. The larger the dome area, the greater the productivity of the field, other things being equal. The Nár-Budhán dome area which extends far beyond the Chinji outcrops may be defined as limited on the north-east by a position just south of Tharochi and on the south-west by one just south of Rájdhani —places which are 6½ miles apart as the crow flies. The positions are of course at points where the outward dipping dome surfaces, after gradually lowering in angle, reach the value of zero or hori-

zontality. As a matter of fact the effective dome area, reckoned at the various levels below the surface that would be accessible to drilling and where oil sands might be struck, would be somewhat less than this, owing to the curvature of the fold. In consequence of the elliptical shape of the dome and the way the major axis tails out indefinitely in north-west—south-east directions, it is hardly feasible to quote any measurements in this direction. But, as before, reckoning the effective part only, it must be at least as long as and probably longer than that in the other direction. We may certainly take 5 miles along each axis of the ellipse as a reasonably safe estimate for calculating the dome area that would be effective at moderate depths, that is to say the area from which upward concentration towards the crests of the dome would be operative, assuming oil to be present.

General amount of dip of the dome.

Among the multiplicity of dip amounts marked on the map it will be seen that the angle of 40° or 45° is very recurrent. It may very well, I think, be regarded as the normal north-east—south-west dip angle. Wherever larger amounts such as 60°, 70° and 80° appear locally, they are generally balanced in the vicinity by others of less than 40°, thus keeping the average about the same.

Longitudinal axial fault: it produces a twin dome.

A longitudinal axial fault, running rather irregularly as regards detail in a roughly north-west—south-east direction, splits the central area of the dome into two halves, producing in fact a twin dome, the duplicated axes of which may collectively be regarded as the axis of the dome as a whole. This fault in its north-west extension at certain places, such as just north of the southern crest and in the bed of the Punch R., is probably of no, or very little, throw, it being almost merged in the fold by which it originated, but to the south-east in the main-stream bed ½ mile south-south-west of Budhán the relative downward displacement on its north-east side is considerable, amounting to over 1,000 feet.

Differential effect of the fault on the north-east semi-dome.

The effect of this downthrow on the structure in the north-east and east parts of the dome is remarkable, as it bends down the Middle Siwaliks of the Pir Durug hill near the 3,785 feet point towards the fault, lowering them nearly to the level of the main-stream. Its effect also on the Lower Siwalik (Chinji beds)

has been similar, and at the same time it splays out the north anticlinal axis at the village of Budhán and south and east of it to such an extent that, what would otherwise have been the pitch of that axis, now coincides with the actual dip of the beds, the amount being between 20° and 35° in radial directions between east-south-east and south-south-east.

South-east half of north-east semi-dome.

This makes the south-eastern half of the north-eastern semi-dome quite unlike other parts of the area and gives to it a much gentler inclination as a whole. This is well illustrated by the longitudinal horizontal section (Section X). To this cause also are due the regular lowering of the dip angle in both Chinjis and Middle Siwaliks in the neighbourhood of this arc of junction, which curves west of Neki and north-west of Bhajowal, and the veering of the general direction of dip from north-east in the Punch river-bed to east-north-east, east, east-south-east, and south-east at Bhajowál. Notwithstanding this more or less regular sweep round of the directions of dip and strike, it is complicated by steep little puckerings at several places north-west of Bhajowál and south-east of the 1,920 feet hill, which however do not affect the general disposition of the mass of the Chinji beds below and the mass of the Middle Siwalik above. They may perhaps be understood as minor puckerings chiefly developed along the line of junction of the Chinjis and the overlying strata.

North-west half of north-east semi-dome.

The north-west half of the north-east semi-dome where it crosses the Punch R. is much more regular, though even here some secondary small foldings are manifest. Some way beyond the Punch R. towards the north-west, the structure ceases to have any dome characteristics and appears to settle down into the normal, rather steep, anticlinal fold, which beyond Darliah probably has much the same character as further north-west at Khaira and Nawan. These inferences could not be substantiated at the time of my visit, as the trans-Punch area was inaccessible for want of any means to cross the flooded river.

Crest of north-east semi-dome.

The crest of this north-east semi-dome is well seen to lie about ¼ mile west of Budhán, the axis cutting diagonally across the little ridge outlined by the 2,000 feet contour which lies between the main stream and the Punch R. The axis and crest have become defined at this point by the broad area of gentle dips south-east of Budhán

giving way to an area more compressed in north-east—south-west directions, so that those gentle dips now coincide with the pitch of the steeper fold, whose chief directions and amounts of dip are now south-west and north-east respectively at about 40° and 50°.

The sketched view (Pl. 15) illustrates the general features near the crest as exposed in and near the point where the axis crosses the main stream-bed.

Anticlinal fold west-north-west of crest.

West-north-west of the crest the anticlinal fold of the north-east semi-dome continues to be of the compressed kind down to and just beyond the Punch. Here the pitch is of course to the west-north-west, being almost equal in amount to the slope of the hill. Here and there at points on the axis near the base of the slope, the rolling round of the dip can be seen to prove the position and pitch of the axis. Although the position of the actual crest is given as above at a point ¼ mile west of Budhán, the whole of the length of the axis from here to the Punch R. must have very nearly a crestal value.

The emergence of the anticline in the river cliff on the other side of the Punch R. is well seen, but was not accessible at the time of my visit.

The above will be sufficient to summarise the chief structural aspects of the north-east semi-dome, with perhaps the additional remark that the mural scarps of the Middle Siwalik soft sandstones and shales, as exposed on the ridge south-east of Kothián, on that near Neki, and that of Pir Durug hill, afford a striking picture of one portion of the dome by the way they partially ring round the north-east side of the area in a panorama or amphitheatre of steep escarpments.

South-west semi-dome.

We now come to the area of the other semi-dome lying south-west of the longitudinal central fault. Here the prevailing dips are fairly steady to the south-west at about 45°, but steepening a little in proximity to the crest. From some places, such as the camping ground at the north-west part of Nár village, the views looking north-west give a good idea of this general direction of dip, the angle just here being rather low (35°). Across the Punch R. the continuation of the same towards the 2,325 feet hill shows a progressive bending of the strike, which is well defined by the hill-side breaking up into several subsidiary curved dip slopes

Thus the dip directions become eventually west-south-west and west by south instead of south-west or south-west by south. This arc of curvature, though not so marked as, is complementary to, that at the north-east side of the dome and is sufficiently pronounced to complete the picture of the dome.

Subsidiary fold.

Near Dugár a subsidiary syncline, followed by an anticline, borne on the main fold, spreads out the width of this part of the south-west semi-dome and carries the outcrop area of the Chinjis in a north-west lobe or projection in that direction. It will be observed that this minor undulation is almost compensated by the very steep dips of 80° at the south-west edge of the Chinjis. This is followed by dips 70°, 60°, 50°, etc. gradually lowering in the gorge of the Punch as the overlying Middle Siwaliks continue the structure towards Rájdhani. The continuation to the north-west of the Dugár minor flexure borne on the main one is well seen near Chhochh and illustrated in horizontal section No. 1.

Axis and crest of south-west semi-dome.

The anticlinal axis and crest portion of this semi-dome lie close up near the fault in a parallel position to the axis of the north-east semi-dome on the other side of the fault. The flexure in this case is compressed throughout its whole visible course and shows no tendency to splay out like the position south-east of Budhán. It may be well studied in the river-cliff on the trans-Jhelum side of the valley, also at the position marked 'Crest' on the 4″ map, and again in the main stream section ⅓ mile north-east of the 2,045 feet conical hill. At all these places the rapid rolling round of the dip is very eloquent as to the pitch of the axis in both directions from the crest. The cliff of crest-sandstone stretching north-west of the position marked 'crest' up to the gap leading down to the Punch valley is particularly precipitous and reminiscent of the Khaur crest-sandstone.

Comparison of structure at Nár-Budhán and Khaur.

We have already seen in section III (*a*) that petrologically the Nár-Budhán dome occurs in rocks that with every assurance may be classified stratigraphically with those of Khaur, although palæontological corroboration of this is so far only very poor. This poverty will probably be remedied in the future, for the discovery of fossil remains of the type present in these rocks is largely a matter of time, depending on

accidental finds made by the local inhabitants, who require to get accustomed to looking for and reporting such finds.

If we now compare the structure, we shall see that the resemblance between the two areas of Nár-Budhán and Khaur is also very complete. The general dip in the Chinjis in both cases is about 40° or 45.° As regards the crest-beds, however, whereas there is a slight steepening in my own area towards the crests of the dome, the position at Khaur is rather in favour of a slight flattening near the crest. In both areas, again, there is an axial fault, making two complementary dome areas, and the general elliptical shape and size of the areas are about equivalent. The area available for drilling, that is, the area of the possible oil-field is also very much the same in both cases, though the somewhat flatter crest at Khaur would give that area a slight advantage. In both cases, also, the size of the general dome-area is large compared with the possible field, or drilling area, so that concentration, equally in the two areas, would proceed from a widely extended underground area.

IV.—PROSPECTS OF OIL.

Does the Nár-Budhán dome contain oil ?

We now come to the question as to whether this Nár-Budhán dome (natural reservoir suitable for containing oil), actually does contain oil. I have already remarked that, so far, no oil seepage has been detected in the Nár-Budhán neighbourhood, whereas there is one, and one only, at Khaur. Mr. Pinfold came on this entirely by accident, and it was not generally known in the history of this part of the Punjab. There is, therefore, still the possibility that some small masked oil seepage may yet be found in the Nár-Budhán area. If it is found, the prospects of there being an oil-pool below will no longer be problematical, but certain.

Oil at Khaur deemed to be not inherent in rocks.

Meanwhile, in estimating the general probability of the case as it stands without the endorsement of a seepage, it is necessary to remember that according to Pinfold the oil at Khaur is not inherent in the rocks in which it is found. The mother-rock of the oil throughout the Punjab occurrences is deemed to be at a much lower horizon in the stratigraphical sequence, namely, among the passage beds between the Hill Nummulitic limestone and the overlying Lower Chharat stage. Apart from

general principles, the particular local evidence for this opinion seems to be chiefly the fact that most of the seepages in the Punjab occur in these lower-situated rocks, although no successful field has ever been developed in them after many and various trials. The oil generated in the mother-rock is supposed to have *migrated* from it up into the oil-bearing sands of the Khaur dome where we must further suppose that it found a convenient underground home for its storage and retention.

The mother-rock of the oil.

The mother-rock is not certainly known in the Khaur area, but lies a considerable distance away both to the north and south. Its presence below the Khaur area is therefore inferred only. It is not at present possible to say whether in the Dandli-Dhannáh area to the north of the Nár-Budhán dome the rocks there represent the particular horizon of what is regarded as the mother-rock, elsewhere. Nummulitic limestone and shales there are, but further investigation and fossil determination are required before one can say definitely whether the particular bed deemed to be the mother-rock is included or not. No seepages were found there by my survey.

Exact method of oil-generation but little understood.

I do not think it would be of any advantage to discuss this particular aspect of the case in further detail now. All oil experts admit that the subject of oil generation is only vaguely known at present, and many details are disputed; whilst the problem of migration is in an equally nebulous state. It does, however, seem reasonable to postulate that by whatever little-understood process the oil attained its present habitat in the Khaur dome, the same process may have operated to bring about its presence in the in every way similar Nár-Budhán dome.

Altitude of crest beds above sea-level.

In this connection it may not be out of place to record that the vertical height above sea-level of the crests in both areas is the same, namely, about 1,500 feet. In view of what may be regarded as a settled belief (among much that is disputed with regard to oil) namely, that oil rises into domes and similar structures by hydrostatic pressure—flowing in as it displaces water until static equilibrium is attained—it may not be without significance that the two dome areas of Nár-Budhán and Khaur agree in being at about the same altitude. On the same admitted principle (that all first

class oil-fields are structurally of the nature of a dome or similar anticlinal flexure) it is clear that, as regards this condition, the Nár-Budhán dome is in an equally advantageous position with Khaur.

All domes do not yield oil.

Dr. Pascoe has, however, pointed out that suitable domes or other ideal structural conditions, even when they occur along the same strike as that of well-known productive fields such as Yenangyaung, do not always yield oil (the Ondwe field in Burma being quoted in support of this). We must, I think, accept this as undoubtedly true and be prepared in any case for possible failure. It indicates that oil-generation conditions (whatever their nature) are patchy in their distribution and not continuously extended in absolute sheet-like form. Hence, when the rocks are crumpled up and thrown into folds, it may just happen that the most suitable fold, namely the dome, may have arisen from what was a barren patch in the conditions of the area.

The caution is one that it is necessary to remember, in weighing the chances; for in oil matters one goes on chances and not on certainties. The question we have to solve is not whether we are *sure* to find oil in the Nár-Budhán dome, but whether it might not be worth while testing it to find out whether it is there or not. One cannot apparently apply the principle of the dome as a sure and certain guide to finding oil, except when it is in sufficient proximity to other proved fields and in rocks of the right horizon. Most oil experts would probably agree that the 80 miles separating the Nár-Budhán dome from Khaur would hardly warrant one in regarding them as being sufficiently closely situated for analogy to be an infallible guide, in spite of the large scale of all the surrounding conditions, such as the enormous thickness and extension, of the formations concerned, and their position at the foot of a range of mountains of such magnitude as the Himalayan range and its continuation ranges. But still the distance may be not too great for purposes of a trial. One may be disappointed by negative results, or on the other hand one may succeed. In the former eventuality one loses the relatively small sum expended in the test borings but one gains experience. In the latter one may have a very valuable mineral asset added to the resources of the State, and one equally gains experience that may lead to the development of other neighbouring fields.

Nár-Budhán dome the best place for a trial.

Among much that is problematical, it remains certain that, of all surrounding localities in the area so far surveyed by me, the Nár-Budhán dome is the most favourable for a trial, insomuch that, if the conditions for oil-formation ever existed in this area, it necessarily becomes the one spot to which concentration would certainly have carried it.

To sum up :—

(1) The Nár-Budhán area and the Jammu hills generally are situated in an oil-bearing belt of Tertiary age common to India and the world.

(2) The particular horizons of the rocks exposed are those which among the Tertiary rocks elsewhere in India and the world are sporadically oil-bearing.

(3) Their petrographical characteristics are identical with those of the nearest known oil-field in the Rawalpindi area, namely that of Khaur, and are very similar to those found in the other oil-bearing regions of India, namely Assam and Burma.

(4) Palæontological evidence so far as it goes is in agreement with this though not very strong at present.

(5) The position of the area as regards the strike, and folding of the strata into disturbance zones is identical with that of Khaur.

(6) The structure of the area is that of an elliptical dome, which is the most favourable of any for concentration and storage of oil.

(7) In most essentials as regards size of dome-area, of possible field area, angles of inclination of the beds, and other general features of the dome, it is almost an exact duplicate of the Khaur area.

(8) The altitude above sea-level of the crest of the dome is the same as that at Khaur, namely about 1,500 feet.

In the above characteristics the Nár-Budhán dome stands alone and has no competitor in the Kotli and Mirpur Tehsils so far as I have examined them. It may have one serious rival in the Jhelum area near Lehri which is at an intermediate position geographically between Khaur and Nár-Budhán. The dome at Lehri is well-known to the oil companies and will almost certainly be drilled

within the next five years. The progress made there will be most instructive and should be carefully followed.

Speculative nature of test operation.

In putting forward the case of the Nár-Budhán dome for favourable consideration it is hardly for me to recommend the Durbar to countenance or encourage an immediate and (what I freely own to be a somewhat speculative) outlay for test drilling operations. The financial side of the question, equally with the technical, needs to be considered; because an undertaking of this kind should only be determined on by those fully prepared for total failure so far as material results go. All oil ventures have this character in different degrees, and no reward of a great success can be gained without some risk. If the Durbar are prepared to back an enterprise of this nature, and if those who do the actual boring recognise it also, well and good: if not, it would be better to wait until further exploitation of the Rawalpindi and Jhelum areas has brought successful oil industries so near to the locality of Nár-Budhán as to render failure there very improbable. This would be the safe method of procedure, *but meanwhile time would have been lost and a market captured by others.*

Whether a sporting or a safe policy be adopted, or whether some happy mean be struck, the data recorded in this note will not depreciate with time and should be preserved for reference.

APPENDIX.

(Notes from Mr. Pinfold's paper on " Oil Springs in the Punjab " read at the Indian Science Congress, Lahore, January 1918.)

Early Efforts.—On Lyman's recommendation (1879) wells were drilled at Chharat, 5 miles north-west of Fatehjang and Jaba. In 1890 more ambitious attempts were made by a Syndicate (Townsend Brothers, chiefly). Canadian drillers put down wells at Sudkal near Fatehjang, Jaba, and Alugud in the trans-Indus range. Some were over 700 feet in depth. Small quantities of oil were found. In 1912 the Indolex syndicate under Professor Preisswerk directed by Professor Zuber of Lemberg, put down wells. All were drilled in compact limestone, and a few gallons of oil were obtained at 1,000 feet. These experiments all indicate that we cannot expect to find oil in marketable quantities in closely compressed limestone anticlines or monoclines, notwithstanding abundant seepages.

The following table in descending order illustrates the stratigraphy of the area :—

Fresh-water conditions—	
Upper Siwalik.	
Middle Siwalik	
Lower Siwalik	Chinji beds. Kamlial beds.
Upper Murree.	
Lower Murree.	
Fatehjang Beds.	
Unconformity—	
Upper Chharat Stage (Shallow-water but open sea conditions).	Nummulitic shales. Limestone and shales.
Lower Chharat Stage (Fresh-water conditions)	Purple and variegated shales with *Planorbis* and mammalian bones.
Hill nummulitic limestone (marine) . .	Uppermost beds with sulphur and gypsum. Shales with coal below; *Cardita beaumonti* bed.

Along the foot-hills of the Kala Chitta range all the above stages are found.

Ten miles further south in the Khaire Murat ridge the basal Murree beds are still present, but they rest on the Lower Chharat stage.

In the Salt Range the Upper and Lower Murree series are absent and the basal zone of the Siwalik system rests directly on the massive Nummulitic limestone, much reduced in thickness.

The mother-rock of the oil is regarded as the passage-beds between the Lower Chharat stage and the Hill Nummulitic limestone, but the oil is accounted for in the Khaur field by vertical upward migration.

Oil Seepages.

(1) *Among the Foot-hills.*

They form a well-defined zone along the foot-hills of Margala and Kala Chitta ranges, stretching continuously from the western flank of the Tret-Murree synclinal through the Rawalpindi and Attock districts, and across the Indus into the North-West-Frontier Province.

The most easterly seepage is at Rutta Hotar, 11 miles due north of Rawalpindi. About 10 miles south-west are the Golra seepages at the extreme east end of the Kala Chitta anticline. The horizon of these seepages is clearly seen to be the passage beds between the Hill nummulitic limestone and the purple and variegated

shales of the Lower Chharat stage. Seepages are numerous in the Chharat fold, 20 miles west of Golra, and they also occur at the Golra horizon and also in the nummulitic shales and in the basal Murree beds. Ten miles further west is the Chak Dalla seepage in chalky limestone of uncertain age.

Other seepages are: East end of Khaire Murat ridge, 14 mile south-west of Rawalpindi. These occur at the extreme east end of the limestone outcrop where it crosses the Bussala stream. The Chharat stages here are absent owing to overlap or unconformity. Another seepage is 4 miles further south-west at a hut named Lundigar at a crest of closely folded Murree rocks.

(2) *Salt Range Seepages.*

At its west end, the uppermost bed of chalky limestone yields oil and native sulphur, *e.g.*, at Jaba. The structure is monoclinal, the limestone dipping steeply beneath Upper Tertiary sandstones and shales.

East of Sakesar, near the centre of the main range, there is a group of seepages at intervals along the junction of the limestone and Siwalik rocks for a distance of 10 miles. The oil seeps from the basal conglomerate or from the top bed of the limestone.

In the Sulgi glen near Amb, a seepage occurs in the heart of the Salt Range (a patch of Siwalik rock resting on limestone and faulted down).

Elsewhere these basal beds are barren of oil and have no seepages.

The Khaur seepage is about 100 square yards in extent and consists of oil-soaked sandstone. The villagers obtained a small flow from this by digging into it. Pinfold got a yield of several tins daily.

On the explanation that the oil at Khaur has migrated up to the Khaur horizon, it is supposed that the mother-rock lies below and with the greater part of the Murree beds absent by unconformity or overlap.

LIST OF PLATES.

THE SUBMERGED FOREST AT BOMBAY. BY T. H. D. LA TOUCHE, M.A., F.G.S., F.A.S.B. (With Plates 17 to 19.)

THE existence of a number of forest trees, submerged to a depth of some 20 feet below mean sea level, but in many cases still retaining their upright position and with their roots attached to the soil in which they grew, was brought to light during the excavation of the Prince's dock on the eastern side of Bombay island about the year 1878. Observations made at the time by Mr. G. E. Ormiston, Resident Engineer, Bombay Port Trust, were communicated by Government to the *Records of the Geological Survey of India*,[1] accompanied by a note by Mr. W. T. Blanford, pointing out that the discovery furnishes evidence of a depression of the land surface in the immediate neighbourhood of ground which appears to have been recently elevated, since it had been shown by Dr. Buist[2] that a raised beach, composed of shelly gravel partly consolidated into a 'littoral concrete,' is found at many places on the western side of the island, extending to a height of 12 feet above high water mark.

Further details of the occurrence, supplied by Mr. Ormiston, were published in a subsequent issue of the *Records*,[3] with notes by Mr. H. B. Medlicott, in which it is stated that samples of the timber from the trees *in situ* had been identified by Mr. J. Sykes Gamble, Conservator of Forests (Bengal), as that of the *Khair* (*Acacia catechu*), a well known Indian forest tree inhabiting the drier parts of the Indian peninsula, both inland and in the neighbourhood of the coast, but not known to occur below the level reached by the tides.[4] Two of the samples were also recognised as teak;

[1] Vol. XI, Pt. 4, p. 302.

[2] *Transactions, Bombay Geographical Society*, Vol. X, p. 179.

[3] Vol. XIV, Pt. 4, p. 320.

[4] A letter to Mr. W. F. D. Fisher, Conservator of Forests, Northern Circle, Bombay, has elicited the information 'that "groves" of Khair (*Acacia catechu*) can hardly be said to exist near Bombay. The tree is common throughout the Thana district and there attains a considerable size, but is generally one of many species in our deciduous forests. It reproduces itself from seed only, but prolifically. In recently felled areas great numbers of seedlings are often seen; later, groups of young khair are not uncommon, but mature trees are usually scattered singly among other species. This gradual thinning out of the species is due entirely to the light-demanding nature of this species. Even

but these were taken from fallen logs, which had apparently been drifted to the position in which they were found. The total number of trees uncovered within an area of 30 acres was 382, of which 223 were erect stumps. One of the fallen logs measured 46 feet in length, with a girth of 36 inches, but stumps reaching 4 feet 6 inch in girth were also met with.

A communication to *Nature* in December 1880[1] by Colonel C. J. Merriman, R.E., Secretary to Government, Public Works Department, Bombay, gives a plan showing the position of some of the trees, and sections of the strata met with during the excavation of the docks. In the latter the position of the trees with reference to tidal levels is clearly indicated.

The conditions under which the trees were found may be briefly recapitulated here. The standing trees were rooted in a scanty layer of soil overlying the decomposed basaltic rock (*moorum*) which forms the floor of the harbour. This had a very uneven surface, being furrowed by wide shallow channels filled in with soil and masses of boulders. The stumps and fallen logs were imbedded in a deposit of stiff blue clay, varying from 6 to 20 feet in thickness, with an almost horizontal upper surface; and above this came 4 to 5 feet of harbour silt or dark brown mud. Some of the stumps were found protruding slightly above the surface of the clay, but all had been broken off at this level, and were completely riddled, to a short distance below the surface, with the borings of *Teredo*, which had evidently attacked the wood from above downwards, since the holes not only became larger as they approached the roots, but were entirely confined to the interior of the stumps. No shells or organic remains other than the wood

in the groups above mentioned, one tree will take the lead sooner or later and the rest will dwindle away by suppression. Generally the process is accelerated by the occurrence of other species of more rapid growth and greater shade-bearing capacity. It therefore would appear unlikely that khair ever occurred in 'groves' but the extremely durable nature of the wood of khair probably resulted in its persistence long after all traces of other trees had disappeared and thus suggested a pure wood or "groves" of khair.

'Khair likes a well drained site and does best on gentle slopes, often stoney, but having soil into which its roots can penetrate to a fair depth. It is seldom found on flat alluvial soil owing to the lack of drainage; if found in such localities the specimens are poor. Given favourable conditions khair comes down to within a few feet above high water limit along the banks of tidal creeks in the North Thana District, which is on the coast about 70 miles north of Bombay. The same phenomenon will be less noticeable in the vicinity of Bombay owing to the sparser tree growth and possibly less favourable factors of locality.'

[1] Vol. XXIII, p. 105.

and impressions of reeds were met with in the blue clay, but a single valve of an oyster, compared by Mr. Geoffrey Nevill with *O. excavata*, Lam., was found in a crevice in the underlying rock. One of the logs had been partially burnt through, affording, as Mr. Medlicott points out, a strong presumption in favour of the occupation of the forest area by man before it became submerged.

The surface on which the trees were rooted was found to range from the level of low water extreme spring tides to 16 feet below, or about 33 feet below the level now reached by the highest tides, indicating a depression of the old land surface to at least this amount.

The blue clay in which the trees are imbedded is apparently identical in character with the clay described by Dr. Buist[1] as occurring immediately beneath the 'littoral concrete' on the western side of the island, with its upper margin slightly below high water mark ; except that at the docks the clay does not contain remains of the roots and stems of mangroves. It also resembles the clay, the 'lagoon formation' of Dr. Buist,—deposited in the backwaters of the island before the sea water was artificially shut out. Its presence below the 'littoral concrete' appears to show that the downward movement to which the submergence of the forest area was due preceded the elevation of the island. The absence of mangrove roots in the clay at the docks may be accounted for by the probability that this area was more remote from the open sea, and the water not sufficiently saline to promote the growth of mangroves.

Thirty-two years after the date of this discovery, in October 1910, while excavations for an extension of the Alexandra dock, situated to the south of the Prince's dock, were in progress, it was reported by Mr. S. H. Savile, Deputy Engineer in charge of the works, that four trees, three of which were standing, had been uncovered under conditions similar to those described by Mr. Ormiston. The spot was visited by the writer when passing through Bombay at the end of the month, and the observations then made have supplied the material for the present note. The trees, one of which is shown in the illustration, were rooted on the surface of the disintegrated rock, the roots spreading out almost at right angles to the trunk, as in the earlier discovery, on the edge of a creek or channel about 200 feet wide and 8 feet deep, which when

[1] *Transactions, Bombay Geographical Society*, Vol. X, p. 181 ; British Association Sectional Reports, 1851, p. 55.

first exposed was filled with clay and drift wood. The stumps of the erect trees were 6 to 7 feet high, corresponding with the thickness of the blue clay in which they were imbedded when found, and from 3 to 5 feet in girth. Some of the clay had been left adhering to the roots of one of the trees, and on examining this carefully the shells of several oysters, with the valves united, and the claw of a crab were picked out. The latter has not been identified; but the oysters, according to Mr. E. W. Vredenburg, belong to the species *O. cucullata*, Born., 'a species abundant in brackish water. They belong to the typical form of the species, though the characteristic ribs are seldom seen, owing to the lower valves being generally attached by almost their entire length.' The fact that the shells were found with the valves united seems to dispose of the suggestion made by Mr. Medlicott, that the single valve found in a crevice of the rock underlying the blue clay at the Prince's dock might have been dropped by some oyster-eating animal—possibly man—; but it may be pointed out that otherwise its presence does not necessarily imply, as he supposed, an upheaval of the old land surface preceding the depression by which the forest was submerged.

The depth below high water mark of the rock surface on which the trees found at the Alexandra dock were rooted is about 40 feet, which gives a minimum value for the total amount of depression. The difference of 7 feet between this and the lowest of the trees previously discovered does not imply that the downward movement varied in amount from one point to another, since it may be due to an original slope of the ground in a southerly direction or towards the coast. Even this figure does not indicate the total amount of subsidence, for it is stated that quantities of similar wood were found at lower levels in dredging out the approaches to the Prince's dock; and it must be presumed that the forest originally grew on a surface elevated to some extent above the extreme limit reached by the tides.

That a considerable subsidence of the rocky floor on the western side of Bombay harbour has taken place thus appears to be fully established—for the fact that the roots of the trees are fixed in the rock precludes the idea that the forest originally grew on beds of loose material which were afterwards undermined by marine erosion, as in the case of the Hampshire submerged forest recorded by Sir C. Lyell in the 'Principles of Geology'[1]—; and it remains

[1] Vol. II, p. 529.

to account for the close juxtaposition of an area of subsidence with one of equally well authenticated and perhaps simultaneous upheaval. The sequence of events appears to have been somewhat as follows :—The forest grew in a scanty covering of soil on a rocky coastal plain, traversed by wide and shallow watercourses and dotted with low hills, the crests of which now probably form the islands in the harbour. A gradual depression of the whole of the coastal area then set in, converting the creeks into back-waters or lagoons, and flooding the forest area with brackish water, so that oysters were enabled to attach themselves to the roots of the trees. Over the submerged area layers of fine clayey silt were deposited, supporting a growth of mangroves along the seaward face, but not in the less saline lagoons which lay behind. Further depression exposed the outer fringe of the deposits to the action of the waves, and masses of shingle and shells were laid down upon them, afterwards consolidated by the infiltration of carbonate of lime into the so-called 'littoral concrete.' The character of the movement appears then to have changed, and to have taken the form of a tilt of the rock surface in an easterly direction, away from the open sea. The comparatively rapid submergence of the inner lagoon thus caused brought the sea in over the deposit of silt, in which many of the trees still remained standing.[1] With the sea water the *Teredo* was introduced, and attacked the bases of the trunks protruding from the silt, so weakening them that they were no longer able to withstand the action of the waves and wind, but were broken off and drifted away. At the same time the deposition of lagoon silt ceased entirely over the area invaded by the sea, and was succeeded by that of the ordinary harbour silt. The simultaneous rise of the seaward face of the island brought the shell gravels and the clays beneath them up to their present position above or near high water mark, and converted the more low lying parts of the island into lagoons and backwaters, in which the deposition of silt, resembling and in fact continuous with the beds which

[1] It is surprising that these trees were not overthrown during the time that must have been occupied in the deposition of a considerable thickness, amounting in places to 20 feet, of the finest silt. The waters of the lagoon must have been very tranquil and far removed from disturbance by the sea waves, and must have been sheltered from storms of great violence. In the Himalayan valleys the trunks of dead trees are frequently seen erect in the silt that has filled the beds of lakes due to the obstruction of the rivers by landslips; but here the silting up process is comparatively rapid, the river water being highly charged with coarse as well as fine sediment.

underlie the 'littoral concrete,' proceeded until the low ground was artificially cut off from the sea.

This is not the only instance of a change in the relative level of sea and land having taken place in a region which is perhaps more than usually susceptible to such movements, since the western coast of the Indian peninsula lies on the edge of the profound depression by which the land, formerly connecting India with the African continent, has been submerged beneath the waters of the Arabian Sea within a comparatively recent period of geological history. The most noteworthy case in point is the depression in the Runn of Cutch caused by the great earthquake of 1819, described in detail by Sir C. Lyell in his 'Principles of Geology'[1] from information supplied by Sir A. Burnes and others. Here also the depression was accompanied by the elevation of a neighbouring portion of the floor of the Runn, the vertical displacement of the ground amounting in all to about 20 feet.[2]

We have of course no means of knowing whether the final phase of the movement in Bombay harbour was accompanied or not by seismic disturbance; but the abrupt manner in which the deposition of the blue clay appears to have come to an end, and to have been followed by a sudden influx of the sea, seems to be in favour of such a supposition.

LIST OF PLATES.

PLATE 17.—Plan of excavation near site of Alexandra dock, Bombay, showing position of tree stumps and 'creek' filled with clay and drift wood.

PLATE 18.—Section along the line A—B on plate 17.

PLATE 19.—View of the tree stump marked X on plate 17, with roots attached; 41·16 feet below high water ordinary spring tides.

Plates 1—3 are from diagrams and photograph supplied by S. H. Savile, Esq.

[1] Vol. II, p. 97.

[2] The evidence for the elevation of this tract, known as the 'Allah Bund,' was considered by Mr. A. B. Wynne (*Memoirs, Geol. Surv. Ind.*, Vol. IX, p. 40) to be unsatisfactory. But in a more recent discussion of the question (*Ibid*, Vol. XXVIII, p. 27) Mr. R. D. Oldham has shown that the main argument brought forward by Mr. Wynne in support of his contention has little weight, and that some upheaval of the area occupied by the 'Bund' probably did take place.

ON SOME INFRA-TRAPPEANS AND A SILICIFIED LAVA FROM HYDERABAD, S. INDIA. BY K. HALLOWES, M.A.Cantab., F.G.S., A.R.S.M., A.Inst.M.M., *Assistant Superintendent, Geological Survey of India.* (With Plate 20.)

Introduction.

WHILE mapping the boundary between the Deccan Trap and the gneiss in Hyderabad (Deccan), I met with some greyish-white calcareous rocks in layers 2 to 10 feet in thickness, which rest directly on granitoid biotite-gneisses of Archean age, and are covered by horizontal flows of Deccan Trap basalt, at Bet Mugnur (18°42′ : 77°36′); Tulni (18°47′: 77°41′); Chota Tudgur (18°28′: 77°39′); Karkheli (18°57′: 77°48′); and between Bet Mugnur and Taukli (18°43′: 77°37′).

These calcareous rocks had the appearance of Lameta limestones, but since Dr. L. L. Fermor[1] and Mr. C. S. Fox found that in Chhindwara, C. P., much of the so-called 'Lameta' was nothing more than calcified gneiss, the specimens were more closely examined. By comparing these rocks with some examples of undoubted calcified gneiss collected in the Central Provinces by my colleague Mr. Fox, who kindly drew my attention to them, I find a resemblance, for both consist of small patches of gneiss in a matrix of calcite.

Microscopical characters.

A slice (slide No. 12,280) of the calcareous rock of Chota Tudgur, shows that the ordinary gneiss of the locality has been entirely replaced by calcite except for a few remnants of strained quartz and orthoclase (Pl. 20, fig. 4).

In a slice (slide No. 12,281) of one of these rocks, taken from a bed exposed in the stream between Bet Mugnur and Taukli, a small remaining, still unaltered, portion of the typical gneiss of the area occurs in the middle of an aggregate of calcite granules (Pl. 20, fig. 3) it consists of orthoclase and microcline intergrown with quartz.

Silicification.

An interesting case of silicification was met with at Hinganey, (18°42′ : 77°45′). At this locality the basal flow of the Deccan Trap Series is composed of

[1] *Rec. Geo. Surv. Ind.*, Vol. XLIII, p. 32, (1913).

a brick red cherty rock (Reg. No. 29/353); this has a conchoidal fracture and contains numerous minute patches of very pale bluish-grey quartz.

Mr. Fox has shown me a specimen of an altered basaltic flow from the Deccan Traps of Chhindwara which is similar to the Hinganey rock; the latter is, probably, a highly altered and silicified basalt, this opinion being shared by my colleague, who has examined the hand specimen and slice.

As in the case of the metamorphosed basaltic flows of Skye[1] the thin section (slide No. 12,283) of this altered lava is seen under the microscope to be composed of secondary silica consisting in part of fibrous radial aggregates of chalcedony, while hollows occur within it which probably represent the initial vesicles or steam blow holes; these now contain infillings of secondary quartz and epidote, the latter mineral having possibly been derived from the metamorphism of the original felspar (Pl. 20, fig. 2). Diffused through the secondary silica are cloud-like masses composed of granules of red oxide of iron which have probably been derived from the decomposition of the magnetite and ilmenite of unaltered basalt. The lava has, in fact, been so highly altered that none of the original minerals or structures have been retained with the exception of the vesicles.

I find, on analysis, that this silicified lava now contains 76·68 per cent. of silica; the silica content of fresh basalt is 46—54 per cent.

On comparing the hand specimens and slices of this rock with some highly altered basic lavas collected in the country immediately south of the volcano of Mt. Popa in Upper Burma they are seen to be alike; in both areas the lavas have been metamorphosed into cherty, brick-red, and pinkish-white, cellular rocks.

Origin.

Dr. Fermor and Mr. Fox have made a special study of the origin of certain rocks from the Central Provinces that are similar to these from Hyderabad. Some years ago they found, in Chhindwara, silicified basalts and calcified gneisses forming, in the first case, the base of the Deccan Trap series, and in the second, the upper surface of the underlying gneiss, in the Kotha Valley east of Chhindboh, at the foot of the hill north-west of Palaspani, and along the base of the basalts north-east of Dhunora. They have arrived

[1] Vide A. Harker, F.R.S., *Mem. Geo. Surv. U.K.*, 1904, p. 46.

at the conclusion that carbon dioxide-bearing meteoric waters, containing in solution lime and silica leached from the Deccan Trap by percolation along the natural channel of circulation between the trap and the gneiss, decompose the silicates of the vesicular basal traps, with the liberation of colloidal silica, to form altered silicified basalt, of which the Hinganey rock is probably an example; and that they then migrate downwards and react in the uppermost horizons of the underlying gneissose complex, dissolving the silica and precipitating the lime to form calcified gneiss, such as that of Chhota Tudgur. From what I have seen of these rocks in the field, in Hyderabad (Deccan), I entirely agree with this explanation of their origin.

As Dr. Fermor and Mr. Fox investigated the subject in the Central Provinces long before my attention was drawn to it in South India, and since, for some time past they have had in view the composition of a paper specially dealing with the genesis of these altered basal traps and infra-trappeans, I do not now propose to discuss the matter further.

EXPLANATION OF PLATE 20.

FIGS. 1 & 2.—Photomicrographs of silicified basalt.

FIGS. 3 & 4.—Photomicrographs of calcified gneiss.

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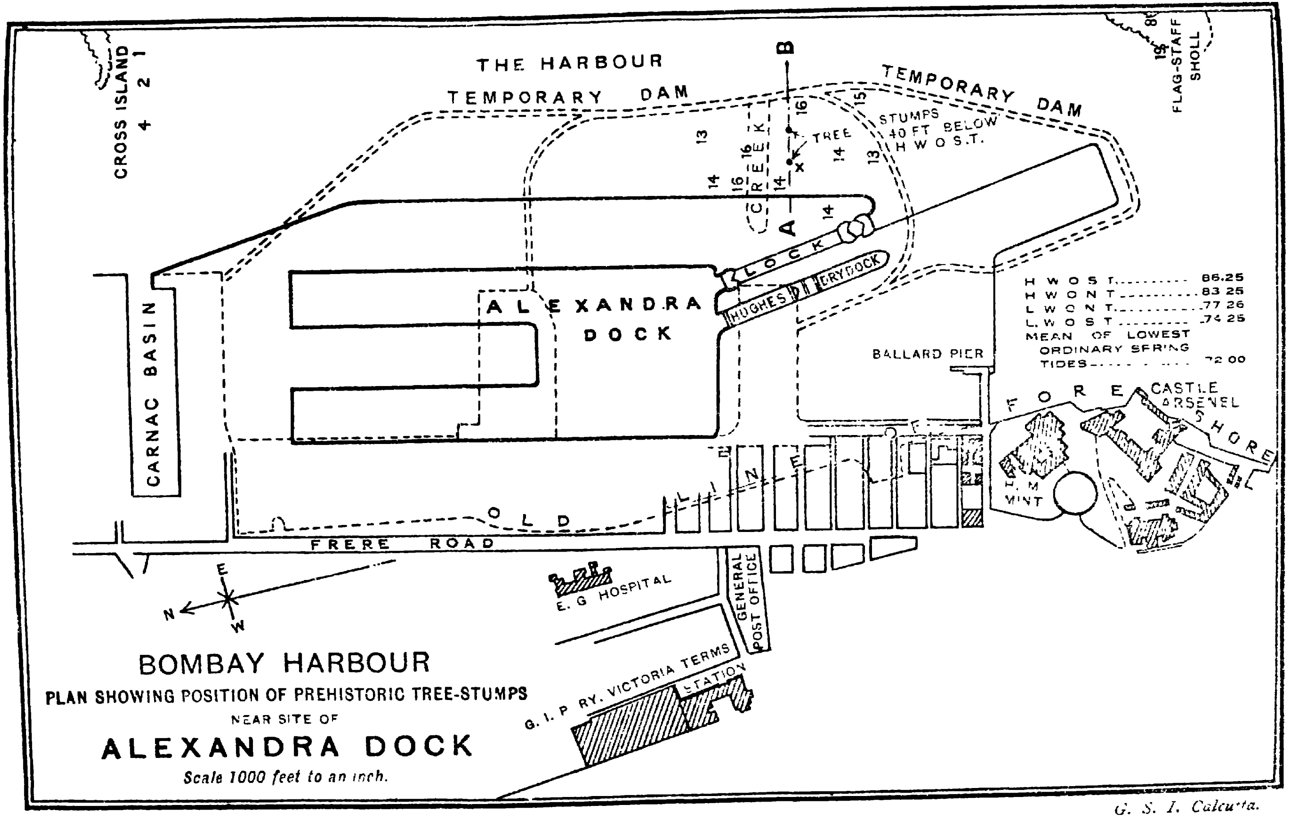
RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA



G. S. I. Calcutta.

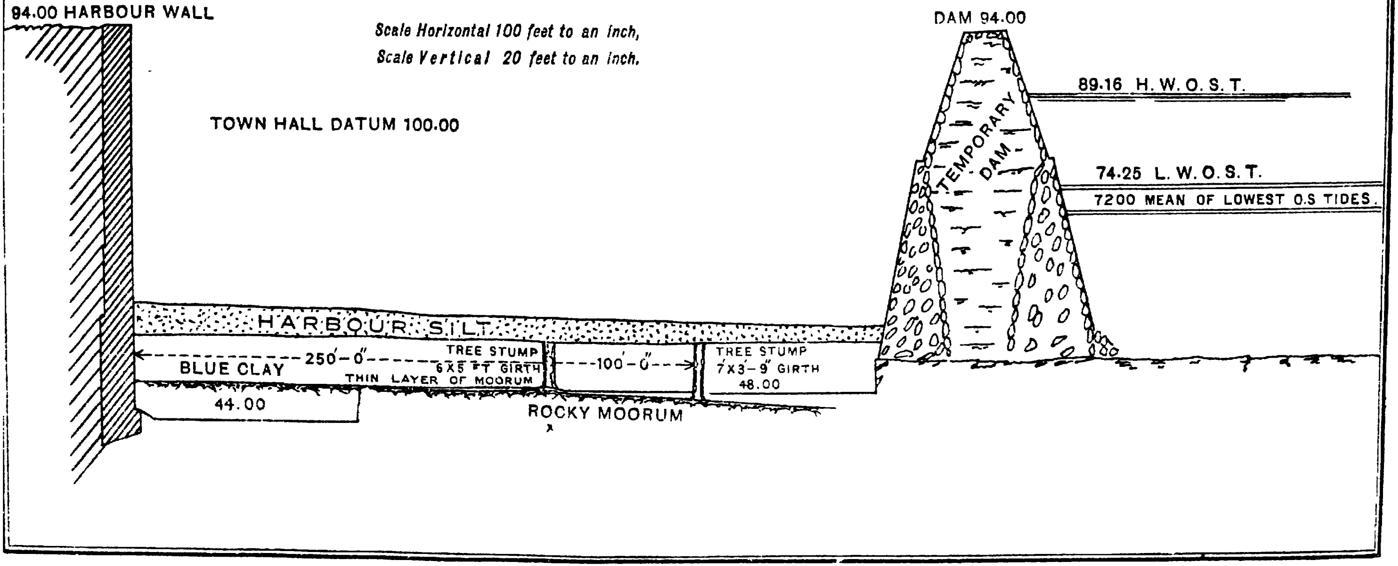
Records, Vol. XLIX, Pl. 18.

BOMBAY HARBOUR

CROSS SECTION ON LINE A-B.

SHOWING STRATA

Scale Horizontal 100 feet to an inch,
Scale Vertical 20 feet to an inch.



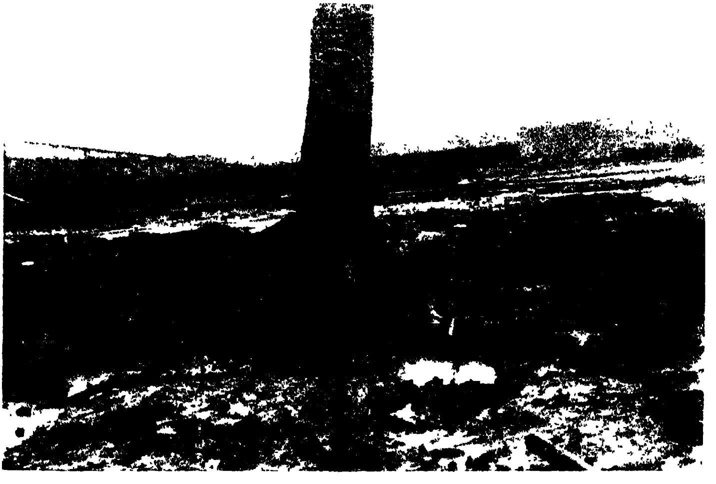


Photo by T. D. La Touche. G. S. I. Calcutta.

PHOTO OF TREE STUMP MARKED × ON PLAN.

(Explanatory skeleton.)

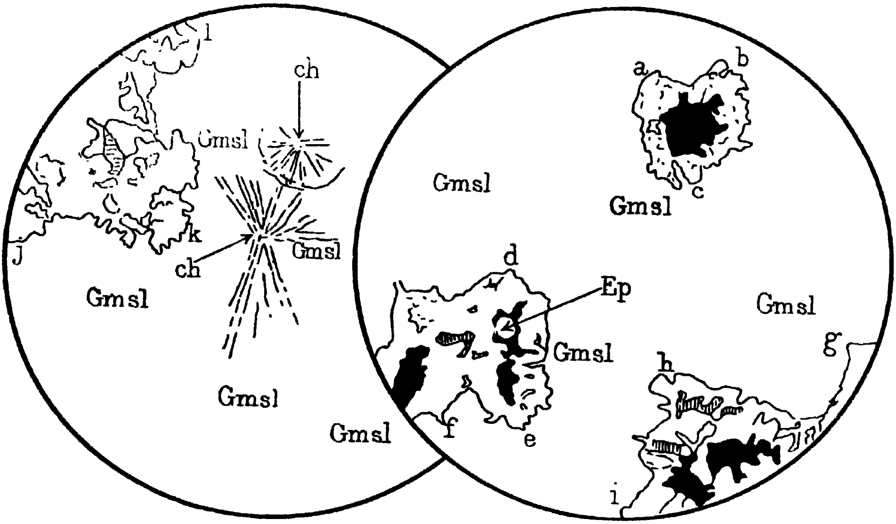


FIG. 1 — Silicified basalt — 12283 Nicols crossed — × 19

jkl = a mosaic of secondary quartz filling a vesicle; *ch* = fibrous radial aggregates of chalcedony
Gmsl = the silicified ground mass

FIG. 2 — Another portion of the same slice — Nicols crossed — × 19.

abc, *def*, *ghi* = vesicles or steam blow-holes of the original lava, lined internally with secondary quartz
Ep = secondary epidote

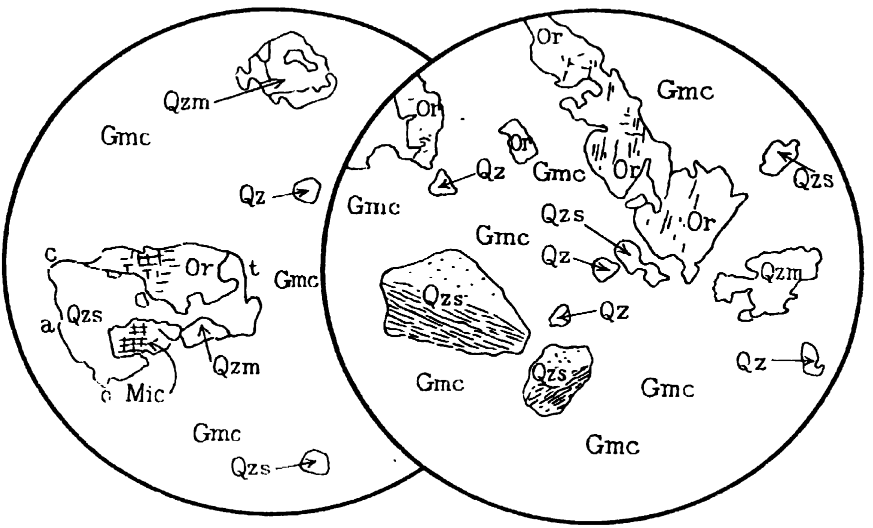


FIG. 3 — Calcined gneiss — 12281 — Nicols crossed — × 14

oact = unaltered remnant of the original gneiss; *Mic* = microcline; *Qzs* = quartz showing strain shadows; *Qzm* = quartz mosaic; *Qz* = quartz; *Or* = orthoclase with cleavage traces; *Gmc* = ground mass composed of calcite, which has replaced the original gneiss.

FIG. 4 = Calcined gneiss — 12280 — Nicols crossed — × 14.

Fig. 1.

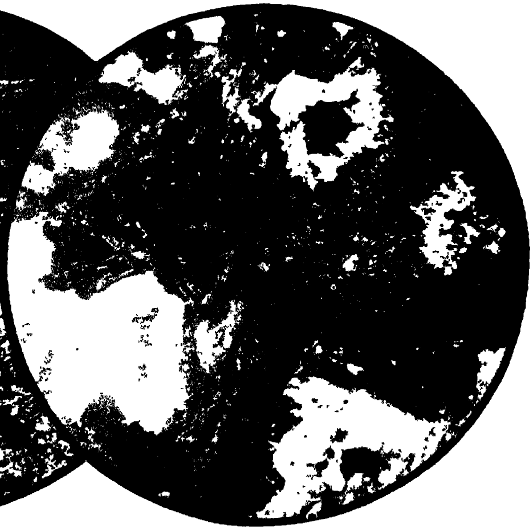


Fig. 2

Fig. 3.

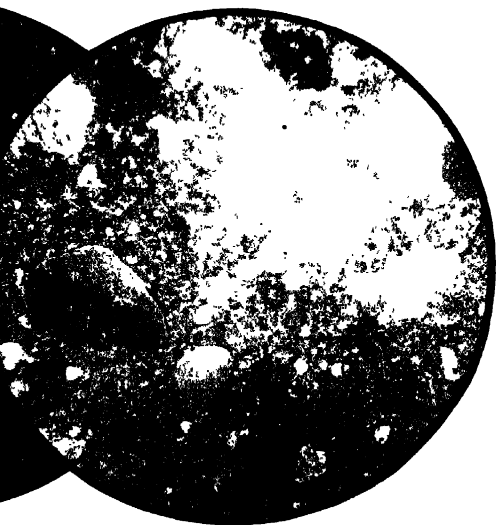


Fig 4

CALCUTTA
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